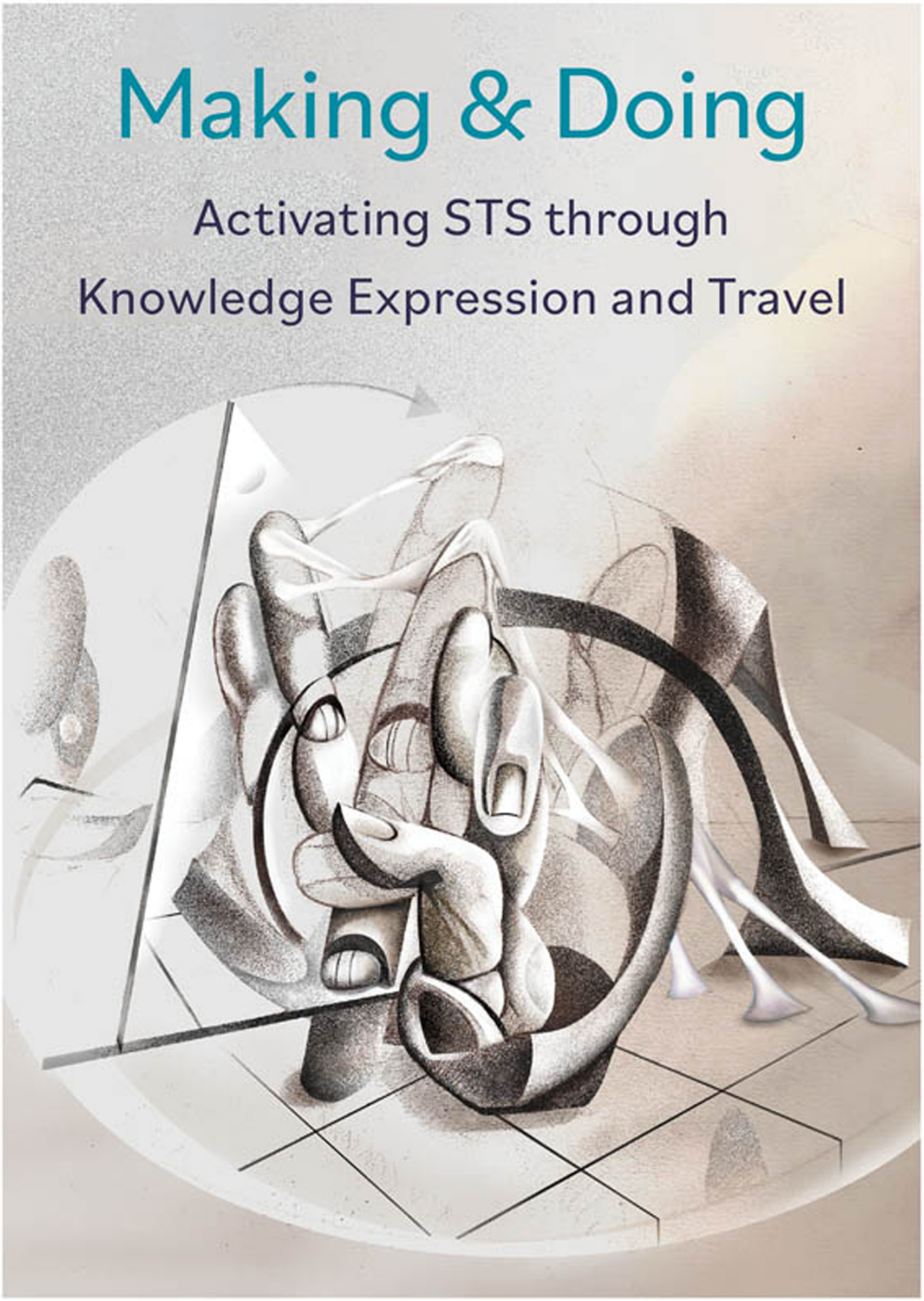
Making & Doing

Activating STS through Knowledge Expression and Travel



edited by

Gary Lee Downey and Teun Zuiderent-Jerak

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MAKING & DOING

ACTIVATING STS THROUGH KNOWLEDGE EXPRESSION AND TRAVEL

EDITED BY GARY LEE DOWNEY AND TEUN ZUIDERENT-JERAK

THE MIT PRESS CAMBRIDGE, MASSACHUSETTS LONDON, ENGLAND

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The open access edition of this book was made possible by generous funding from Arcadia—a charitable fund of Lisbet Rausing and Peter Baldwin.

The MIT Press would like to thank the anonymous peer reviewers who provided comments on drafts of this book. The generous work of academic experts is essential for establishing the authority and quality of our publications. We acknowledge with gratitude the contributions of these otherwise uncredited readers.

This book was set in Stone by Westchester Publishing Services, Danbury, CT.

Library of Congress Cataloging-in-Publication Data

Names: Downey, Gary Lee, editor. | Zuiderent-Jerak, Teun, editor.
Title: Making & doing : activating STS through knowledge expression and travel / edited by Gary Downey and Teun Zuiderent-Jerak.
Description: Cambridge, Massachusetts : The MIT Press, 2021. | Includes bibliographical references and index.
Identifiers: LCCN 2020044365 | ISBN 9780262539975 (paperback)
Subjects: LCSH: Communication in science. | Communication of technical information. | Science--Study and teaching--Research. | Technology--Study and teaching--Research.
Classification: LCC Q223 .M35 2021 | DDC 507.1--dc23
LC record available at https://lccn.loc.gov/2020044365

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for

Anne Zeilfelder Downey (1920–2003)
who taught me to take interest in others

and

Clarence James Downey (1923–1987)
who taught me to find joy in the process
—Gary Downey

To my students and other colleagues
for your inspiring commitment to positive world-making
and creative scholarly learning
—Teun Zuiderent-Jerak

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ACKNOWLEDGMENTS

As a demo account of STS making & doing, this book joins other scholarship that activates STS through nonlinear forms of knowledge expression and travel. We happily and gratefully acknowledge all the techniques, devices, infrastructures, and, especially, selves that are expanding STS scholarship by turning STS lessons onto STS work, both through and beyond this volume.

We are especially grateful for the committed contributions by authors of the ten demo accounts in this book, as well as the many agents and practices that animate their projects. We have greatly appreciated the willingness of authors to accept our invitations to write their projects and to produce reviews of two other demo accounts and our draft introduction as imagined coauthors. We are equally thankful to Kim Fortun for her gift of two reviews that, likewise, contributed to draft demo accounts. We also thank three anonymous reviewers whose thoughtful and insightful critical commentary on the draft manuscript became crucial contributions to the final version. And we thank Laura Zeefat for drafting an index that expresses the scholarship of STS making & doing in ways that help it attach to interested readers.

In this project, the name Katie Helke quickly came to stand for the massive array of editorial and production techniques, devices, infrastructures, and selves that are enabling this volume to express STS sensibilities and make them travel into new empirical and scholarly arenas. As acquisitions editor for STS at MIT Press, Katie strongly encouraged us to launch this experimental endeavor and thoughtfully guided us through the infrastructures of prospectus review, contract development, external review, editorial recommendation, final editorial board review, and production. Reading and responding to everything closely and with a sharp eye, she is also responsible for this book having a concluding coda. Thank you, Katie, for everything. We also thank Laura Keeler, assistant acquisitions editor, for carefully attaching the appropriate production practices to the manuscript and ensuring its flow

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through to publication. And we thank production editor John Donohue and copy editor Mary Ann Short for significantly increasing the quality of the volume by adding themselves and their knowledge practices to it.

We are grateful for the funding provided to MIT Press by the Arcadia Fund to make this volume available as an open access publication. Adding open access to print publication dramatically expands the book's reach, hopefully accelerating the expansion of nonlinear scholarship that expresses STS knowledge through STS sensibilities and attaches it in empirical arenas. We are pleased for these demo accounts and authors to participate in an infrastructure of scholarly travel that prioritizes access.

Our joint journey into the lexicon of STS making & doing began with a hike in Virginia in 2013. Each of us brought to the collaboration prior commitments and track records dedicated to experiments in learning through interactions in our fields of scholarly work. Our collaboration continued with Gary establishing and Teun serving on the STS Making & Doing Committee during Gary's presidency of the Society for Social Studies of Science (4S; 2013–2015). We acknowledge crucial early contributions from other members of that first committee, as well as from the 4S Council and its officers (see the coda for details). The collaboration expanded through our joint preparations for the 2014 Summer School of the Netherlands Graduate Research School of Science, Technology, and Modern Culture (WTMC), for which Gary served as anchor teacher and Teun as speaker and curriculum coordinator (together with Geert Somsen, Maastricht University). We are pleased to acknowledge the students at that summer school—Alejandro Balanzo, Wieke Betten, Tessa Cramer, Michael Anthony Dizon, Claudia Egher, Susan van Hees, Suyash Jolly, Marije de Jong, Kristen Koopman, David Louwrier, Floortje Moes, Thomas Mougey, Carla Alvial Palavicino, Tineke van der Schoor, Frans Sengers, Maria Alejandra Tejada, Bart Walhout, Sarah Weingartz, Willemine Willems, and Esther de Wit, as well as WTMC's director, Sally Wyatt, and contributing STS interlocutors Stuart Blume, Erik Fisher, Sheila Jasanoff, Cory Knobel, Brian Martin, Jessica Mesman, and Helga Nowotny. Gary also acknowledges research assistance from Kristen Koopman in preparation for the summer school.

The STS Making & Doing program, as introduced and maintained by the 4S, remains possible though the enthusiastic and committed work of members of the STS Making & Doing organizing and awards committees. The coda acknowledges all by name and in context. We have also greatly appreciated the sustained support that Lucy Suchman, Kim Fortun, and Joan Fujimura, as 4S presidents, and 4S Council members and officers have given to this program. The many contributors to the programs at 4S meetings in Denver, Boston, Sydney, and New Orleans, and at the 4S/EASST meeting in "virtual Prague" have made clear the importance of positioning making & doing work as central to STS scholarship. May the intellectual passions and academic joys that come with demonstrating and accounting for STS making & doing continue to fill those rooms.

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Gary: My contributions to this project have benefited greatly from an exceptionally supportive and collaborative work environment in Virginia Tech's Department of Science, Technology, and Society, as well as from the university's openness to experimental work in engaged scholarship. I learned much from graduate students and visiting interlocutors in the experimental courses "What Is STS For? What Are STS scholars For?" and "Engaged STS." My evolving commitment to nonlinear STS scholarship gained much from early collaboration with Juan Lucena, multiple discussions with Matthew Wisnioski, generative exchanges with Kacey Beddoes and Brent Jesiek, inspiring work with many graduate advisees as they sorted their own STS trajectories, and an especially timely conversation with Joseph Dumit. I acknowledge collaborations with many scholars working to build critical participation into the heart of engineering studies scholarship, especially through the International Network for Engineering Studies (INES), and while I served as editor of *Engineering Studies*. I am grateful to many colleagues in the 4S who offered advice, critical commentary, encouragement, and labor to recognize and advance nonlinear STS scholarship while I served as president. I was shocked to encounter such interest and energy when my term began, then overjoyed to learn that the commitment and scholarship were there all along. And Teun, I am especially grateful to you. I had thought I understood learning. I did not. We came together around an emergent vision of STS making & doing as scholarship. Your attention to reflexive learning became central for me, preventing us from reproducing the linear model through an image of knowledge travel. I smile at remembering how the differences between us never melted away but produced a continuing resonance that made the collaboration that is us so much greater than just two. Thank you, my friend.

Teun: I am especially thankful for the early support I received from the generative working environment of the Healthcare Governance group, headed by Roland Bal, at the Erasmus School of Health Policy and Management, Erasmus University Rotterdam, and the strong, shared commitment I experienced there to the theoretically informed study of change by realizing it. Dedicating substantial time to the development of the Making & Doing program within the 4S became possible through a research fellow grant in the Future Research Leaders program that was run by Linköping University, Sweden, and that was embedded in the inspiring Department of Thematic Studies—Technology and Social Change. This program, which is primarily based on giving confidence rather than targets, gave me the chance to dedicate time to infrastructural work that had otherwise been unthinkable. Maintaining equally strong commitments to infrastructural work and to theorizing is something I could not have imagined learning without the many exchanges with Geof Bowker. Thank you for your deep commitment to caring experiments, with technology, theory, text, and spirituality, and for our friendship. I truly enjoyed and learned from the close collaboration with Michaela Spencer in preparing and curating the Sydney

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Making & Doing program. This work has received further support from the Athena Institute of the Vrije Universiteit Amsterdam, a collective so deeply involved in a wide range of STS making & doing scholarship that it is incredibly hard to keep up with all the inspiring work. It feels like a true academic home. Doctoral students and other colleagues make every day a deeply creative, joyful experience. It feels like a privilege to be involved in (y)our projects. I am grateful to Joske Bunders, Barbara Regeer, Jacqueline Broerse, Marjolein Zweekhorst, and so many others for growing the academic institutional ecology I would have wanted to help grow, had I had the chance and had I imagined it possible. It is a pleasure and a privilege to be given that chance now. Throughout all those years and while I moved between institutions, Gary Downey has been a source of continued inspiration. Our friend/scholar-ship is something I deeply cherish. You showed me how to consider STS work, *including* teaching, as a profound encounter of concepts, practices, bodies and selves—and how I should learn to reverse that order.

Just as this form of scholarship blurs the boundary separating scholar identities from other identities, so does it call special attention to those intimate relationships that infuse us with energy and purpose and give us strength to push on.

Gary: To Marta, my forever partner, I rely every day on the remarkable trust that you and I share. Your extraordinary generosity and enthusiastic embrace of living keep our work positioned as fulfilling parts of our life together. I love you. Jamie, Megan and Adam, Michael and Kate, and Leah, my children and children-in-law, and Nicholas, Andrew, Casey, and Ben, my grandsons, I draw inspiration and intense pleasure from watching and learning from your energized engagements with your own lives. Being there continues to be a great privilege and source of endless joy. I love you. Thank you, all.

Teun: The boundaries between my scholarly and other identities are so blurred as to be chimerical. Sonja, you are already so much part of this book that acknowledgments would invoke a distance that does not exist. For this, I am deeply grateful.

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INTRODUCTION

Activating STS through STS Sensibilities

Gary Lee Downey and Teun Zuiderent-Jerak

Scholarship in Science and Technology Studies (STS) has frequently built on critiques of the linear model of creation, diffusion, and utilization. Developing alternate accounts, STS researchers have shown that sciences and technologies always develop in specific settings and that myriad agents and agencies participate in their production, expression, and travel. With repeated studies showing how the development, materialization, and utilization of the facts and artifacts under examination were entwined right from the start, it is no surprise that many STS scholars have cultivated practices to turn STS lessons about nonlinearity onto their own work.

The most visible practices have involved research. Some concentrate attention on the academic paper or book, exploring how STS publications might respond to unforeseen uses and reactions beyond the boundaries of the field or be framed to produce desirable outcomes.[1] Other practices open up the taken-for-granted relation between knowledge production and publication of the academic paper or book to call attention to emerging and potential configurations of *knowledge expression* (Bowker 2011) that extend beyond them. Along with early experiments with alternative literary forms for performing STS knowledge (Ashmore 1989; Ashmore, Myers, and Potter 1995), interrogating relations between knowledge expression and knowledge production has expanded to include collaborating with practices in design, digital studies, and indigenous art (Calvert and Schyfter 2017; Vertesi et al. 2019; Watson-Verran, the Yolngu Community at Yirrkala, and Chambers 1989) and experimenting with a range of material enactments in both performing and producing STS knowledges (Latour and Weibel 2005; Law and Urry 2004; Lezaun, Narres, and Tironi 2017; Lury and Wakeford 2012; Marres, Guggenheim, and Wilkie 2018; Zuiderent-Jerak 2015). Via findings about the nonlinearity of knowledge development and the materiality of scholarly practices, STS research has increasingly embraced challenges to explore how its own forms of knowledge have been and might be expressed.

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Alongside research, STS has also long provided intellectual and institutional space for scholarly projects that explore novel practices for achieving *knowledge travel* into empirical fields in consequential ways. Such projects often have not made their way into publications or other scholarly venues that traditionally express STS research.[2] Yet by insisting in STS-informed terms that the explicitly nonlinear work in making knowledge travel is scholarship, too, they challenge and expand the boundary around the notion and practices of STS scholarship itself (Downey 2009; Zuiderent-Jerak 2015). The number, contents, and scope of such projects have expanded as STS scholars increasingly extended their investigative and experimental work to include the trajectories of STS knowledge flows beyond the boundaries of the field. Calling heightened attention to relations between knowledge expression and knowledge travel, they complement and, sometimes, overlap with research initiatives that elaborate relations between knowledge production and knowledge expression.

One outcome of these scholarly interests in turning STS lessons onto STS work has been the rise of *STS making & doing* as a collective label for projects that expand STS scholarship by adding attention to both knowledge expression and knowledge travel alongside dominant commitments to knowledge production (Downey and Zuiderent-Jerak 2017; Wylie, Shapiro, and Liboiron 2017).[3] Initially, interest in promoting any and all scholarly projects that extend beyond the academic article or book justified piloting a program of STS Making & Doing at annual meetings of the Society for Social Studies of Science (4S). Energetic participation in the first program, combined with the multiplication of related initiatives across STS and STS-affiliated organizations, expanded scholarly attention from making visible nonlinear scholarly projects to critically examining how STS scholarship of all sorts grapples with issues of knowledge expression and knowledge travel beyond the boundaries of the field. After all, the expression and travel of STS knowledge even through academic texts involves practices of making & doing that exceed simple diffusion and utilization (Guggenheim 2015). This volume extends the STS Making & Doing program by experimenting with narrative demonstrations and interpretive accounts of individual projects, examining and reflecting on what happens when STS scholarship actively entwines knowledge expression and travel with knowledge production.[4]

The purpose of this book is to explore how STS making & doing projects contribute to and advance STS scholarship. In ten *demo accounts*, contributors both present and critically assess how their projects express STS knowledge and seek to effect its travel into empirical arenas beyond the boundaries of the field, as they understand it. In the process, these demo accounts attend simultaneously to the engagement of actors and practices in fields of STS work and to reflexive learning from those actors and practices. Contributing authors generously accepted a difficult challenge to critically account for both what happens when their projects seek to inflect understandings and actions in empirical arenas through STS learning and how they themselves learn from their interlocutors and the settings in which they do and share their STS

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work. The resulting collection thus adds to ongoing initiatives that turn STS lessons onto STS work by exploring and documenting how diverse, and sometimes divergent, STS projects express and enact two-way, or multiple-way, flows of STS knowledge. Together, these demo accounts show that STS making & doing projects contribute to and advance STS scholarship precisely by expanding it to include practices of knowledge expression and knowledge travel.

CURATING OPENNESS, FOLLOWING OVERLAPS

How might differently positioned scholars write their projects in STS making & doing? We were uncertain at the outset. We had previously observed that scholarly initiatives in STS making & doing appear as multiple as STS is as a whole (Downey and Zuiderent-Jerak 2017). It was clearly incumbent on us not to try to capture these projects in some holistic way, claiming and attempting to cage in advance a multiplicity that we actually want to document, highlight, and further stimulate.

We did know that we wanted the demo accounts to be grounded in empirical cases so that readers could experience and recognize the terms and complexities of a given project in STS making & doing, including its passions, commitments, struggles, and pathways of travel. At the same time, we resisted the notion that narratives of STS making & doing have to include rhetorical techniques or literary forms that are as experimental as the projects they present. We did not want to presume that existing modes of scholarly writing and analysis are not adequate to both demonstrate and account for practices that perform the scholarship of STS making & doing. Decisions about narrative elements and structure had to be made by contributors themselves.

We did anticipate, correctly as it turned out, that contributors would find it important to write in the first person. Nonlinear projects in STS making & doing tend to position specific scholars in specific empirical fields. When one is demoing and reporting on relations between knowledge expression and travel, it rarely makes sense to imagine and construct an anonymous maker and doer, and it can be problematic to do so. It can risk stripping the project of specificities in the practices of knowledge expression and travel that may prove crucial to the scholarly import of those practices.[5]

At the same time, we did expect that the challenges involved in producing first-person versions and accounts could prove discomforting to authors, including ourselves. In particular, every demo account confronts what emerged as a recurring issue: how might first-person STS demo accounts critically examine relations between knowledge expression and knowledge travel without degenerating into self-promoting autobiography that falls outside of STS scholarship entirely? Not an easy task. We asked contributors to include their dilemmas, frustrations, and failures, especially when these generated new practices that might not have occurred had their work not taken the form of making & doing scholarship.

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We started the project by soliciting interest and an "abstract/summary/outline" from self-identified STS scholars whose work spanned a range of topics and territories and appeared to intersect with the threefold aim of "making STS knowledge and expertise travel to new areas, . . . producing and expressing STS knowledge and expertise in novel ways, and . . . reflexively furthering learning and theory development within STS."[6] The invitations included the terms "expression" and "travel" but without definition or elaboration. We had previously used these terms as signposts at 4S conferences, a joint conference of EASST (European Association for the Study of Science and Technology) and 4S, and in a chapter of the *Handbook of Science and Technology Studies* (Downey and Zuiderent-Jerak 2017) to call attention to flows of STS knowledge beyond the boundaries of the field (see also Downey 2014, 2015; Downey and Zuiderent-Jerak 2016). In addition, without defining STS, we did look for relatively developed projects that address simultaneously the knowledge, or technical, dimensions of issues involving science, technology, and medicine and the social, or nontechnical, dimensions, as these are conventionally understood.[7] Asking contributors to work through empirical case material "to a maximum extent," our guidelines for draft manuscripts emphasized attending to flows of learning, "including (or even especially) learning by the STS scholars involved."

Contributors directly encountered one another's projects by reviewing two other demo accounts and, sometimes, sharing manuscripts. We designed an iterative internal review process to enable contributors to take stock of the scholarly trajectories in other projects while articulating their own. The review process was necessarily open (i.e., not anonymized). We asked contributors to imagine themselves in conversation with an author or authors who could not respond.[8] Their first charge was to articulate how a project "construe[s] and enact[s]" scholarly practices of STS making & doing, focusing in particular on what makes the project "especially compelling." Contributors then had to explain limitations or outstanding issues by "taking care to include specific suggestions about how to address them." By effectively transforming each contributor into a coauthor of two other demo accounts, this step helped all to reflect on the framing and positioning of their own. It also invited them into the editorial process of balancing the acknowledgment and presentation of divergent multiplicity with analysis of parallels and overlaps.

A realization that the relationship between knowledge expression and knowledge travel could serve as more than a signpost for scholarly contributions in STS making & doing emerged indirectly, but clearly, while we curated the initial draft demo accounts and subsequent review process. In the first place, we were surprised to see contributors almost invariably position their projects outside of and, at times, in opposition to an assumed mainstream of STS scholarship. Although mostly unspecified, this mainstream of "safe" scholarship consists of empirical inquiry, formal theorizing, and publication in academic journals and books.

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To us and, ultimately, to contributors, this outside was but another inside of STS scholarship. Perhaps the shared sense of exclusion or marginalization was actually instructive. In reviews, contributors encouraged one another and, seemingly, themselves to trust that their "unsafe" projects are indeed making and doing STS scholarship and to accept the challenge of demonstrating and specifying how. The issues they identified in one another's work took a significant step past guideposts. In particular, they included repeated suggestions to elaborate empirical interactions in the field, to clarify flows of STS knowledge, to position the STS scholar more explicitly in relation to the field, and to document learning both in the empirical field and by the STS scholar(s).

Drawing on the reviews, our requests for revisions challenged each contributor or team of contributors to elaborate the practices through which their project expresses STS knowledge and effects its travel into its empirical arena and to account for the sorts of practices that emerged as a result. As the ten final versions arrived, we inquired more specifically into how the specific practices enacted in each project (1) express STS knowledge for other audiences and settings, (2) produce travel for STS knowledge into and across the empirical field, (3) make the scholar visible in the scholarly practices, and (4) facilitate learning on the part of the STS scholar. As we reviewed answers to these questions, it became clear that each raises a distinct set of scholarly issues, addressed differently by different projects. At the same time, our commitment to curating openness and multiplicity also produced something of a surprise. We found all the projects to include practices that express STS knowledge through "STS sensibilities" and attach those sensibilities to practices in empirical fields.

1. EXPRESSING KNOWLEDGE THROUGH STS SENSIBILITIES

In introducing STS making & doing through our chapter in the 2017 *Handbook of Science and Technology Studies* (Downey and Zuiderent-Jerak 2017, 227), we identified "Techniques, Devices, and Infrastructures" as elements of STS engagement that respond to *frictions* (Kember 2003) encountered in the field and perform alternate images through STS knowledge and identities. As we watched the manuscripts in this volume emerge, we were so struck by the recurring appearance and critical performance of STS-inspired techniques, devices, and infrastructures that we began to call them STS practices themselves. They are what STS scholars make and do as they express STS knowledge for other audiences and settings.

Every project in this collection identifies in STS terms one or more frictions to which it responds. These frictions are places and practices where dominant images of science and technology lose their smoothness and become multiple. A courtroom encloses science solely in the figure of the expert witness, excluding victims.

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Self-trackers lack ways to question and reflect critically on the data they produce. Bureaucratic procedures that create the academic migrant as a statistical category leave out asylum seekers. Market-oriented governmental policies in science and technology tend to omit the users of research results. Public debates on technoscientific issues take place on a large scale in social media but get left out of governance procedures. Fish laboratories focus narrowly on some obligations while ignoring many others. Hospital evaluation and improvement practices emphasize innovation through external consultants who miss important knowledge on-site. Initiatives to decarbonize the electrical grid actually leave in place hydrocarbon infrastructures and supporting knowledge infrastructures. Evidence-based medicine is not attached exclusively to the randomized controlled trial. Learning engineering challenges students to divide their worlds into two parts, right and wrong.

Developing making & doing projects in the midst of frictions positions those frictions as pivot points between conventional STS knowledge production and initiatives that activate STS by including knowledge expression and travel. The questions and potential practices multiply as they gain directionality. Could this friction be about boundaries, subordination, demarcation, presupposition, invisibility, multiplicity, obligation, some combination of the above, something else, or what? Might a friction be stable or shifting? How does the way one approaches it open up or close down potentials to engage with its actors and practices? How might a potential project construe a friction, localize it, benefit from it, or alter it? By seeking to add STS knowledge, does a project aim to smooth, interrupt, displace, replace, introduce, reframe, keep open, or maximize a friction, or perhaps just get a localized setting to recognize a friction in the first place?

With some exceptions, these contributions include relatively few theoretical concepts or citations of research findings, making their connection to STS theory as it appears in academic articles and books seem relatively loose. Even the contribution by Michael Guggenheim, Judith Kröll, and Bernd Kräftner (demo account 3) which takes pains to position itself intellectually in relation to other ongoing work, describes its incubations as "allowing the logic of the project to destabilize STS methods and media so much that they are no longer recognizable as social research." It would be difficult to describe these STS demo accounts as applying or otherwise prioritizing formal theory from STS research through the practices they make, do, and provoke. Yet at the same time, it is equally clear that every project conveys STS knowledge. This knowledge appears in the techniques, devices, infrastructures, and versions of themselves and others that the scholars make and do in confronting the frictions they identify.

As STS practices, the techniques, devices, infrastructures, and selves in these projects express STS knowledge through forms designed to fit into or attach to the empirical fields to which they are added and become traceable. The demo accounts are filled with examples. Workers who become visible participants in a courtroom rather

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than invisible observers. A software infrastructure that tries to stabilize the figure of a general end user who explores data. A public office in a shipping container that moves academic asylum seekers from marginal spaces to a central square. Local management desks in remote rural settings that enact sociotechnical alliances around water. Visualizations of data on public debates that travel fast when wrapped up as facts. A laboratory protocol that sees fish as food, political citizens, and grandmothers. A hospital infrastructure focused inward on existing strengths. Imaginative space that extends beyond detoxification. A working group that explores methods for appraising and including different knowledges in medical guidelines. An elective course shared via a teleconference.

We came to see these practices as enacting *STS sensibilities*, by which we mean observable instances of knowledge expression that enact STS knowledge contents but without necessary reference to their formal linguistic formulations. This is different from existing uses of the term "STS sensibility," which tend to focus attention on the relations between STS knowledge expression and production (i.e., the practices and outcomes of research). John Law and Vicky Singleton suggest, for example, that ANT (Actor Network Theory) is "probably best understood as a sensibility," which to them refers to "a set of empirical inferences in the world, a worldly practice, or a lively craft that . . . is created, recreated, explored, and tinkered within particular research practices" (2013, 485). When produced in research, or "knowledge-making" as the program committee for the 4S 2017 conference put it, STS sensibilities tend to become capabilities located in persons. The committee framed the conference theme "STS (In)Sensibilities" by positioning sensibility as "the ability to grasp and to respond" that is achieved, or not achieved, by "STS scholars, teachers, and activists" (Suchman et al. 2017, 5).

Quite differently, as these demo accounts repeatedly indicate, the scholarship of STS making & doing opens the aperture on STS sensibilities to direct attention to their prospective and actual material lives and trajectories beyond the boundaries of the field. Relevant scholarly questions expand to include exploring how practices that express STS sensibilities may or may not be responding to frictions encountered in the field. They also include following how those practices actually attach to ongoing knowledge practices in the empirical arena, or not. The analytic spotlight opens up to focus on those things and people inhabiting the empirical arena that take on challenges to integrate STS sensibilities with existing knowledge practices.

2. PRODUCING TRAVEL BY ATTACHING STS SENSIBILITIES

Our *Handbook* chapter, "Making and Doing: Engagement and Reflexive Learning in Science and Technology Studies," describes the ecological dimensions of making & doing as consisting of audiences for STS learning—which may include partners, engaged practitioners, and those enacting STS sensibilities in the field—as well as

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reflexive STS learning through feedback and reframing. Consider the early STS finding that knowledge developments in science and technology do not simply follow an internal technoscientific logic but are shaped by all kinds of dynamics and are thus nonlinear in their emergence and effects. This bit of STS knowledge joins settings beyond the boundaries of the field as an STS sensibility to the extent that the practices that carry it begin to interrupt appeals to linearity and introduce alternate dynamics. As nonlinear movement, expressing STS knowledge as STS sensibilities for other audiences quickly becomes quite complex, posing significant theoretical challenges. How does a scholar of STS making & doing frame this, or some other, knowledge claim via practices that may be admissible or taken for granted at gatherings of STS scholars but perhaps not easily elsewhere?[9]

Expressed through techniques, devices, infrastructures, and selves, the practices of STS making & doing *attach* STS sensibilities in empirical arenas. In this volume, the ten projects attach STS sensibilities to interrupt a knowledge hierarchy, elevate subordinated knowledge, reframe assumptions, make visible hidden knowledge, emphasize the obligations of the person in the scholar, highlight the social in technical materiality, perform the multiplicity in technical visions, make visible hidden knowers, recast calculation as sociotechnical infrastructure, and blur a boundary around certified knowledge. As one moves from project to project, it quickly becomes clear that each draws on a distinctive intellectual trajectory to frame and attach STS sensibilities.

Unless attached STS sensibilities are simply ignored, practices of STS making & doing provoke interactions and add relations that become sites and vehicles for extending STS learning. It is just that such learning often appears implicitly in subsequent actions, presupposing or performing STS sensibilities without reference to their academic origins. Some examples: surprised judges convert a cafeteria to an extension courtroom in which STS commentators flourish. The software infrastructure generates a miniature social arena that engineers are not equipped to organize. Academic asylum seekers agree that they should themselves serve as the carers of their module. The social development ministry and agricultural technology institute agree to form a public-public consortium to support a lab that enacts both. Politicians, municipal leaders, and union officials learn that teachers in one municipality are not united in their critique of the school reform. The university grants permission to dispose of fish guts as food rather than as hazardous waste. The surgeons and pathologists jointly develop a written template to describe the orientation of the specimen in the patient's breast. Leaders of the aerosolar balloon project withdraw the assignment to identify scientific payloads specifically for environmental justice advocates. The board of an international guidelines association founds a working group to appraise and include a wider set of knowledges than evidence from randomized controlled trials. Advocates of active learning for engineers make a move to locate culture within the technical practices of engineering.

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The attachment of STS sensibilities thus produces travel for STS knowledge. The metaphor of travel for the flow of sensibilities and, hence, learning appeals because it suggests diverse trajectories with multiple starting points rather than emanations from a privileged scholarly core. It calls attention to movements with different temporalities and spatialities. It comes with companions, some of which you may end up liking more than you thought—or less. Better than "diffusion," which imagines passive spread and appears to aim for uniform concentrations, "travel" calls attention to active transport through practices that are both distinct and traceable. Better than "impact," which imagines an external force producing collision, "travel" can involve multiple agencies with multidirectional trajectories. The analysis of knowledge travel opens up generative questions of origin and destination, propulsion and resistance, with a call for specificity. Overall, the notion of knowledge travel helps make nonlinear modes of knowledge expression something to follow and trace with interest and critical attention.

At the same time, actually following attachments of STS sensibilities in empirical arenas adds complexities to the practices of STS scholarship by generating as many questions about the contents and implications of such attachments as there are trajectories of contact and flow. What do STS attachments add to an empirical setting? Subtract? Through what configurations of practices and relationships? What are key entry points for a given STS sensibility? How do STS sensibilities encounter and interact with other sensibilities that may be active in the setting or also seek activation? Through what relations does a project actually attach the scholar to the setting? With what implications for the project and the person? Do other attachment arenas appear open to these STS sensibilities?

These demo accounts illustrate how the travels of scholarly projects in STS making & doing can be uncertain and unpredictable, inviting research into their contingencies and possible alternate formations. We also see that practices of STS making & doing regularly attach to one another, inviting similar research into their relationships and possible alternate configurations. The directionalities of scholarly practices in STS making & doing matter because their specific movements make STS knowledge claims and insights become situated in distinctive and variable ways. We see in these demo accounts scholars repeatedly confronting variations of the questions "Where is the STS sensibility in this practice now, and what does it become in relation to what?" And "What other techniques, devices, infrastructures and selves might we/I try adding? And what do these practices mean for me, or us?"

3. ACCEPTING THE SCHOLAR'S VISIBILITY IN ATTACHING SENSIBILITIES

Adding a program with projects in STS making & doing to the annual meeting of the 4S generated a great deal of enthusiasm among presenters and attendees alike.

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What could account for that? But wait: is even asking such a question, inquiring into the contents of scholarly enthusiasm, a violation of proper scholarly judgment and assessment? While reading the STS demo accounts in this book, you might find yourself coming away with an elevated sense of appreciation for STS scholars who have been working long and hard to devise and experiment with ways of expressing STS knowledge that have a chance of attaching to empirical arenas beyond the boundaries of the field. To us, enthusiasm for projects in STS making & doing feels quite similar to the excitement we can feel when encountering research literatures in STS that enable us to explore an issue in new ways and propel us to conduct research that might speak or contribute to those literatures. Yet there is a difference.

As a mode of scholarship, STS making & doing involves attending not only to what the scholar makes and does but also to how the scholar and the scholarship get made and done in the process. Most academic infrastructures endeavor to make scholars invisible (e.g., anonymous peer review). They do so incompletely. Expanding the notion and purview of STS scholarship to explicitly include STS scholars as persons calls attention to how they themselves embody and become vehicles for the travel of STS sensibilities. Relations between scholarly and other identities of the person become salient, along with the practices that perform them.[10] Feminist studies have long undone the problematic split between scholar and person in the production of sciences and technologies (Faulkner 2007; Haraway 1991; Harding 1991; Keller 1993; Wajcman 1991). Growing commitments to care in STS research are undoing the masculinist treatment of objects of study and concern and calling new attention to relations between the figure of the knower and that of the known (Jerak-Zuiderent 2020; Martin, Myers, and Viseu 2015; Puig de la Bellacasa 2011, 2017; Russell and Vinsel 2016). STS making & doing adds to these scholarly moves by putting the body of the scholar directly on the line as that body endeavors to express and attach STS sensibilities.

Demonstrating and accounting for the visible presence of the scholar in the scholarship becomes one of the most vexing issues in STS making & doing. Beyond the situated positioning of standpoint, which has gained increased acceptance in scholarly writing, adding ourselves as persons to our demo accounts may risk undermining the intellectual value of the practices and learning they seek to offer. Blurring the boundary around one's scholar identity to acknowledge the presence and participation of other identities raises the fearsome prospect that the scholarship will dissipate and decline into personal opinion, idiosyncratic experience, or other non-STS practice. It might become ad hominem or ad feminam, about us rather than our object of study, producing the loss of both scholarship and scholars from a recently emerged field with still-vulnerable infrastructures. Even as we, as authors, want our work to be connected to our names, especially if this leads to acknowledgment through citations, we routinely strive to keep invisible our bodies and selves.[11] This boundary becomes porous in STS making & doing and, hence, in STS demo accounts. Indeed, those very

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moments in which demo accounts reveal or perform commitment or aspiration, making them feel transgressive or otherwise unsafe, may also be providing insights into a key dimension of their scholarly import as practices of knowledge expression and travel.

The attachment or nonattachment of STS sensibilities in empirical arenas marks experiences infused with affective contents. Such contents provide significant indicators of meaning, indexing what STS sensibilities are or could be contributing to empirical arenas through the complexities of knowledge expression and travel. Affective contents indicate intensities of welcome or resistance, obstruction or encouragement. They reveal specificities in relations established or spurned and distance covered or remaining. Every demo account in this volume draws attention to some kind of affective content as they report building and rebuilding practices of knowledge expression and travel. In STS demo accounts, commitments—even or especially when speculative—are not extraneous, marginal, or otherwise supplemental to the scholarly contents of the work. They are core, constitutive, and central.

Consider Hsin-Hsing Chen yelling "Score!" as a commentator in the extended courtroom, or Yi-Ping Lin exclaiming excitedly that she had caught a foul ball (in demo account 1). Both moments call attention to inconsistencies in a court case that was designed to keep workers invisible. One way these scholars knew they were attaching STS sensibilities in the courtroom was that it felt good and, as such, worth the enormous personal investments involved. Their demo account makes clear that they judge themselves to be both authorized and compelled to report such experiences in an account of STS making & doing.

Dawn Nafus (demo account 2) asserts at the outset that she wanted to work hands on with code because "helping people work with data on their own terms mattered to me." Adding herself to her text as person did not diminish the account by making it about her. Rather, it articulated the meaning of this initiative in STS knowledge expression and travel, helping us map and assess how and why she adopted the strategies she did, with what hopes, expectations, and consequences. Michael Guggenheim, Judith Kröll, and Bernd Kräftner (demo account 3) describe how the "humiliation" that academic asylum seekers experienced when marginalized on the job market is evidenced by certificates that are designed to perform visual officialdom but have become worthless. What does it mean, they ask reflexively, for a project whose practical logic is to make such asylum seekers visible, if that logic also has the effect of affirming the invisibility of those without certificates? Time and time again, Hernán Thomas, Lucas Becerra, and Paula Juarez (demo account 4) found their work proposal and action plans "fall outside the rationales of existing public institutions" that relied on linear or determinist thinking. It took five years of frustrating negotiations with all parties to get unanimous support. The authors compress into two words the bodily commitments and practices that, for them, transformed the meaning of research and identity of the researcher: "we persisted."

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Torben Jensen, Andreas Birkbak, Anders Madsen, and Anders Munk (demo account 5) share their uncertainty about ethical responsibility as they watch powerful stakeholders carry away their digital maps and devices and use them to mobilize against other actors. The anxiety they experience calls attention to a contingency in knowledge expression and travel that confronts all projects in STS making & doing and for which their project attempts to take account. Following commitments in STS making & doing calls attention to the importance of iterating STS sensibilities while critically highlighting the challenges of iteration. Max Liboiron, Emily Simmonds, Edward Allen, Emily Wells, Jessica Melvin, Alex Zahara, Charles Mather, and All Our Teachers (demo account 6) call attention to power relations and ethical obligations in a different way when they admit that they are still "working on" their own assumption of access to fish guts and recognition that their "access precludes other access, uses, and relations." Jessica Mesman and Katherine Carroll (demo account 7) explicitly work to make visible the hidden knowledge in the everyday work of health care professionals in order "to make a difference." They challenge themselves to recognize and analyze who is becoming what, because doing video reflexivity adds on STS sensibilities. Attaching STS sensibilities in empirical fields produces encounters with other sensibilities that require much scholarly work to sort out. Navigating those encounters is necessarily part of our scholarship.

Nick Shapiro (demo account 8) repeatedly evades assignment on the aerosolar project to serve as spokesperson for environmental justice advocates by "discern[ing] what scientific payloads would be most useful" to them. He worries that the assignment would limit his project to pluralizing authoritative claims about the environment rather than challenging a presupposition shared across otherwise competing positions. Teun Zuiderent-Jerak (demo account 9) is surprised to find his coinitiative to appraise and include different knowledges in guideline development lead not to collaborative work rebuilding knowledge infrastructures but to philosophical writing on styles of reasoning. What must he and his project become now, he asks, as the members of the working group he founded are more interested in epistemology than in knowledge infrastructures, and he finds himself largely agreeing with them? Gary Downey (demo account 10) watched his interlocutors express enthusiasm about positioning culture within engineering as a step toward promoting active learning. He could not share the enthusiasm, however, because they were reinscribing a demarcation between technical and social. He realized that his project needs a new entry point.

In every case, affective content is also STS content, a performance of STS knowledge. By expressing knowledge through STS sensibilities that make STS travel, these projects act on behalf of some version of the field, albeit for other audiences. Each time we STS scholars step into empirical arenas and offer ourselves as embodiments of STS knowledge, we also challenge ourselves to articulate once again what counts as STS, how it may look different in a new setting, and what it means to do STS work. The issue is nontrivial, about much more than strategy and tactics in downstream

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diffusion and utilization. The first STS Making & Doing program generated great enthusiasm in part because it authorized the performance and sharing of joy, angst, and pretty much everything in between. The affective contents of presented projects became available for colleagues to experience and interpret because the scholarship of STS making & doing requires its scholar-practitioners to be visible.

The experimental demo accounts in this volume take steps to reveal the person in the project, documenting the flows of learning that such presence helps to produce, as well as what sensibilities and knowledge might be gained reflexively in the process. Likely all the authors would acknowledge that such documentation and associated analysis remains emergent and incomplete, and, for many, more than a little bit uncomfortable. We assert that these STS demo accounts stand out by making the effort in the first place.[12]

4. REFLEXIVE LEARNING THROUGH STS SENSIBILITIES

Attaching STS sensibilities in empirical arenas often provokes reflexive learning on the part of the STS scholars involved. Just as travel is not about diffusion from a scholarly core, so reflexive learning is not measured by its relation to knowledge production alone. Practices of reflexive learning may head in different directions. They may indeed turn to inflect the results of research, including modes of STS theory. They may also walk back to reassess and reconsider a motivating friction. Carrying new questions about the self in the scholar, they may proceed to interrogate relations among scholar and nonscholar identities. They may set out to initiate further iterations of knowledge expression and travel, perhaps with different itineraries.

Practices of reflexive learning in these demo accounts tend to point toward another round of sensibilities and attachments. Since court procedures did not formally change to admit workers as bearers of knowledge, perhaps a documentary might help others to gain such permission. Difficulties stabilizing the general self-tracker shifts the software's focus to nonprofit groups that already offer stable figures. A training scheme to pair asylum seekers with academic organizations does not work out, motivating founding a new organization to integrate them. A local management desk risks distraction from the water project and makes house fumigation its first collective action, combating the Chagas disease that afflicts the entire population. An ethical commitment to multiplicity leads to an insistence that all formulated visions, including ones that weaken the teachers' union, remain publicly available online. A scientific lab that recognizes its relations and tries to fulfill its obligations finds itself making many compromises. New clinalysts take the initiative to carry on by themselves, both documenting how they do safety and figuring out how to do it better. The pursuit of radical alterity necessarily includes incrementalism even though it risks dissolving into reformism. Workgroup members challenge the focus on more diverse knowledge appraisal infrastructures by giving priority to retheorizing styles

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of reasoning in evidence-based medicine. Infrastructuring culture into engineering education might better begin with the student's entry into the curriculum rather than through an elective addition.

Note how demo accounting for reflexive learning in an STS making & doing project tends to direct attention beyond the boundaries of the narrative. Highlighting the temporality and spatiality of the project, the demo account names itself as an episode, acknowledging its own incompleteness. Something came before, and something different will likely come after as project episodes overlap with career practices and trajectories. And once again, questions multiply. What sorts of specific practices produce acceptance and adoption of STS sensibilities? Does the learning that occurs in empirical fields speak in any way to the STS scholar's initial apprehension of a friction? What has become of that friction by virtue of the project? And what of the attachments of the STS scholar? Does achievement of learning in empirical settings motivate new STS research? How about another making & doing project, or phase of the current project, to further extend the reach of its sensibilities and learning?

Each demo account in this book thus calls for its own extension. It is a call that, in principle, knows no limitation. The trajectories of projects in STS making & doing are coterminous with the field, as the project construes it. As their practices perform the field, they also extend its reach. To date, the temporal and spatial limitations of scholarly careers have likely contributed to the relative devaluation of STS scholarship in making & doing. Projects that appear not to be scholarship have too often emerged, prospered, and expired with the scholars who initiated them, including when the projects did not mimic scholarly conventions closely enough to support an academic career. The project that is this book maintains that producing and sharing demo accounts can enable STS as a whole to extend itself through the reflexive learning they provide.

TEN DEMO ACCOUNTS OF STS MAKING & DOING

Dissecting these demo accounts through four analytic questions has disaggregated them. It divided them up. Something got lost in the process. Disaggregating projects in the way we have thus far has stripped them of the flows of STS sensibilities that constitute them and call attention to what is especially compelling about each. It is precisely the demo quality that attracts great interest during the STS Making & Doing program, where one can walk from project to project and begin to understand what is at stake in each. By gaining the opportunity to examine and review dozens of demo accounts of such projects, might one be able to gain a better handle on just how active that STS scholarship has been, is now, and could become?[13] The text that follows assembles the disaggregated analyses into summary introductions that isolate specificities in how the project expresses STS knowledge for other audiences and settings, producing travel for STS sensibilities into and across the empirical field,

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making the scholar visible in the scholarly practices, and facilitating learning on the part of the STS scholar. We know there are many such projects. Here are ten.

DEMO ACCOUNT 1: ADDING WORKERS TO THE COURTROOM (YI-PING LIN AND HSIN-HSING CHEN)

"Score!" The court had opened an extension courtroom in the cafeteria, and STS scholars created and staffed the new position of "commentator." The commentator explained to the crowd what was happening on the televised screen when an attorney cornered a defense witness using questions that commentators and others had designed weeks earlier. Akin to a baseball game, scoring happened infrequently and usually only after a long buildup that often included another STS scholar texting back and forth between attorneys in the courtroom and researchers on campus. The high court in Taiwan had been unprepared to accommodate the hundreds of former Radio Corporation of America (RCA) workers and their families who campaigned to be present for the court sessions. They were violating the ontological status assigned to them. Yi-Ping Lin and Hsin-Hsing Chen show what they and other STS scholars did and had to do to help workers become and stay visible as holders of knowledge.

Parties to a civil lawsuit typically attend only the initial session, final oral summations, and announcement of the verdict. Otherwise, attorneys introduce them through witnesses and documents. The parties gain legal embodiment as the judge dictates to the clerk a written record of testimony, painstakingly negotiating details with the attorneys and witnesses. The RCA workers and families, representing more than five hundred former employees, wanted to attend and be seen because they were the victims. Their complaint, the first collective lawsuit in Taiwan, claimed that RCA had knowingly exposed its workers to hazardous chemicals that had caused miscarriages, lupus, and fifty-six types of cancer. Their very presence was a knowledge claim.

At one point, the Chinese-language academic journal *STM* (*Taiwanese Journal for Studies of Science, Technology and Society*) appeared on the attorneys' table. In that issue, Chen (2011, 45–46) had shown how Japanese courts had expanded notions of causation from "scientific certainty" to "reasonable medical certainty," with clear implications for this case. Lin (2011, 61–112) had shown that existing epidemiological knowledge about worker exposures had omitted a crucial category of worker: young women who had worked for relatively short periods of time. This STS knowledge about gender bias in clinical studies later proved crucial when RCA lawyers pointed to epidemiological studies linking one chemical to kidney and liver cancer but not to breast and cervical cancer. They were unaware that such studies were "mainly done on populations of male workers." Recognizing this omission in a courtroom exchange that felt like a baseball game, Yi-Ping Lin emerged exclaiming, "I've caught a foul ball!"

The *STM* issue had added STS scholarship and scholars to a case that was calling public attention to environmental and health costs from Taiwan's rapid industrial

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expansion through collaborations with, especially, US-based companies seeking low-cost labor. It had made the scholars visible to the workers as knowledgeable advisers who could move back and forth between the factual medical and environmental claims and the evolving state of the court case in both local and international terms. By appearing on the attorneys' table, the journal attached to the courtroom itself not only STS sensibilities but also formalized STS knowledge.

Had STS scholars not joined the case, it is likely that the workers would have remained largely bystanders. Apart from the few who would have provided sharply constrained testimony as witnesses, they would have been effectively invisible, observers of their own legal diagnoses. By accepting and enacting the identities of backstage commentator and attorney support, as well as advisory group member, documentary film maker, and so on, STS scholars helped enable them to become and remain visibly present, even as silent interlocutors. The multitude of contributions that STS scholars made to the case expanded the category of plaintiff in a civil lawsuit to include bodies in the courtroom. Alongside work that makes STS knowledge on the status of evidence present in court (Cole 2009; Lynch and Cole 2005), this STS sensibility extended the courtroom itself, connecting the courtroom to public controversy. The scale and persistence of the scholarly efforts also helped STS gain status and visibility as an academic field in Taiwan and helped Taiwanese STS scholars make contributions well beyond the country.

DEMO ACCOUNT 2: INSERTING A THIRD FIGURE BETWEEN SOFTWARE AND USER? (DAWN NAFUS)

"In the course of these encounters," writes Dawn Nafus, "my participants got better at seeing what I saw and came to anticipate what needed doing and doing it." Working as a senior researcher at Intel, Nafus was testing an early-stage software design she had codeveloped that would help users learn things about themselves by juxtaposing different kinds of data and looking for patterns. One test user found it revealing, for example, to examine not only the average number of steps she was taking each day to keep fit but also the actual total numbers. She discovered that too much exercise was triggering her autoimmune disease. A group of family caregivers collected data from a device that tracked their sleep patterns, looking for insight about their own levels of stress. A community group examining the effects of air quality on health correlated their heart rate and blood oxygen levels with data from local sensors of pollutants. Nafus helped test users decide on what data to collect and input and how to experiment with different correlations, and she watched as they offered interpretations and speculated on what other sorts of analyses might be done with additional data. Nafus and her engineering team members started off building a tool that could do exploratory analyses of different types of data and that was based on earlier research that identified possible uses. The tool instead emerged as a sociotechnical

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infrastructure called Data Sense. In the process of building it, team members had to become themselves the new kind of figure they were trying to produce.

Software engineers use the distinction between visible "figure" and invisible "ground" to focus their work. Software highlights the visible pathways it offers users via its features while hiding the stacked layers of computations on which the pursuit of those pathways depends. In the Data Sense project, Nafus bore primary responsibility for figure—user desires and specifications—while engineers ruminated over the computational layers of ground. Such is the engineer's image of an STS scholar, preserving the technical-social dualism they take for granted by assigning the social to her. But Nafus brought with her another image of figure, that of the "cultural figure." It is an agent who operates in cultural and social formations, such as the "wildly heterogeneous . . . data culture" of the present. Software engineers appear in this framing initially as "data wranglers." As they worked together to build a new kind of web-based software system, both Nafus and the engineers crossed the boundaries they initially saw as separating them.

Nafus and her teammates want to help "self-trackers," an emergent category of person; they "work with data on their own terms." In one way or another, anyone who engages with software has become a self-tracker, devoting increasing amounts of time to collecting, organizing, cleansing, and analyzing data (Dumit 2018). Nafus finds it "intellectually interesting" and "socially beneficial" to help people ask new questions about data that pertain to them and reflect critically on "the circumstances in which the data was collected." It turned out that the software engineers did, too.

Team members learned how difficult it is to build software that departs significantly from the narrow image of a tool serving a single purpose or pursuing a small set of goals (i.e., software with a stable figure in both senses). In particular, how can one system process heterogeneous streams of data whose characteristics cannot be specified in advance? They found that one correlation in Data Sense might require the ground to process five streams of data, another twenty-five. The first might require the visible figure to parse the data by time of day, the other by smoothing data across variable time periods. Adding the ability to count steps per hour makes sense, but counting heart beats per hour does not. Also, users whose identities tilted toward that of the data wrangler found it easier to use Data Sense to ask new questions than those with little knowledge of coding. Such users could easily become overwhelmed if Data Sense presented them with too many options to organize and manipulate data.

The team developed a system of ground and figure for "onboarding" users, helping them learn enough computational concepts and practices to upload data and begin to manipulate it. But Nafus found over and over again that "the figure of the end user who explores data" could not be attached and stabilized in general terms. As a company, Intel is known for producing semiconductor chips for a wide range of applications, or figures. Its niche in computing is the general. Data Sense emerged as a software product that produced a "miniature social arena" when Nafus herself

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was present with users to have a "dialogue in data," and she was "making meaning together" with them.

In the terms we're using here, Data Sense performed an STS sensibility by requiring a continued collaboration with the STS scholar in order to produce the third figure in a reliable way.[14] Building the computer engineers' technical figure for a new kind of software also required building and attaching a new kind of cultural figure. Nafus learned that Intel was not positioned to facilitate the interpersonal engagements and socially sanctioned moments necessary for people to "sit down with data" and discover things about themselves through Data Sense. But perhaps some groups are? Nafus was able to ask what sorts of alliances needed to form. In doing so, Nafus helped Intel shift Data Sense away from a software analog of the general microchip to begin negotiating with nonprofit groups that could use Data Sense to produce third figures in locally meaningful ways. Data Sense could not race to the end, helping the self-tracker emerge as a uniform general category. Instead, it is helping localized self-trackers to continue emerging a little at a time.

DEMO ACCOUNT 3: INCUBATING THE ACADEMIC ASYLUM SEEKER (MICHAEL GUGGENHEIM, JUDITH KRÖLL, AND BERND KRÄFTNER)

One member brought a white doctor's coat to the office as a sign that she could not use it anymore; another brought a dictionary of medical terms connecting Somali to German and compiled to help other refugees; a third suggested putting up maps of home countries. All had accepted invitations to join an exhibition project designed to make visible the "situation of scientists that became asylum seekers" in Austria. The office was in a shipping container placed on a central square in Vienna between the Charles Church and the Technical University. Participants used the office to converse with passersby about their lives and experiences during six weeks in summer. The conversations about academic asylum seekers made up one of twelve interactive modules in an exhibition visited by some fifteen thousand people. Each module had "module carers," project members who were trained to interact with visitors through the objects and controversies on display. In this module, the asylum seekers served as the module carers themselves.

The exhibition is an "incubation," which the authors define as "a socio-technical device that uses situational, social and time-based pressure to invent the social and represent it with a wide variety of media" (Guggenheim, Kräftner, and Kröll 2018, 65). The demo of their incubation accounts for the sequential development of the project, focusing on shifts that could not be anticipated in advance. The project started with the goal of highlighting how academic migrants get made through bureaucratic procedures and statistics as they cross borders through student exchange programs, fellowships, and visiting professorships. But encounters with an academic asylum seeker led the organizers to focus more specifically on how the tag "asylum seeker"

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silences everything that makes up the person's biography as an academic. What qualities of academic asylum seekers are invisible to the state or actively made invisible by the state? And how might such qualities be made visible in public settings? How should they be represented?

Over the course of a year, the project organizers learned to recognize representation as "chimera" (i.e., as a weird and distant appropriation that belied its own goals). The organizers became curators of the exhibition they describe, and they decided with the asylum seekers who joined the project that the latter must speak for themselves. They had fled to Austria from Sudan, Côte d'Ivoire, Chechnya, Ukraine, Georgia, Libya, Palestine, Kyrgyzstan, Somalia, the Democratic Republic of the Congo, Afghanistan, Iraq, and Iran. They lived in refugee shelters, together.

The curators offered participants office space in an unused café as long as their grant could cover the rent. There the participants could develop their own projects away from the shelters and "outside the pressures of the incubation," which held regular meetings. As it became clear that academic asylum seekers should represent themselves in the exhibition, it also became clear that fixing the location for the module would make it more visible than having it move. Locating it in the city center would grant it maximum visibility. The central location itself also called attention to the more hidden refugee shelters. Participants wanted to post their BA, MA, and PhD certificates on the walls. The certificates visibly named the knowledge and skills that participants were sacrificing by seeking asylum in a country that did not recognize them.

The incubation evolved past the multitude of conversations at the exhibition. Recognizing that the state made invisible the knowledge and skills of persons tagged asylum seeker, the curators had set up a kind of exchange and training scheme that worked to pair refugees with relevant academic organizations. They hoped that the exhibition might also make publicly visible and document the workings of this new training scheme. When they encountered difficulties in pairing, the curators and participants founded a new organization, called Researchers without Borders. The purpose of the organization was to help asylum seekers make the case that they had integrated themselves into Austrian society: they were integrated by becoming members of a professional organization called Researchers without Borders. Through the exhibition and the new organization, project participants effectively created and attached the category of "integrated academic asylum seeker," persons with professional knowledge and status that made them worthy of state certification and legal standing as "refugees."

By following an experimental and procedural logic in the incubation, the STS scholars had become interviewees in articles about the exhibition, documenters of integrated asylum seekers, and founders of Researchers without Borders. To make these shifts, they needed to move away from "the logic of written STS," along with its media commitments. They then returned to those logics to produce this demo account as a "second, separate act."

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DEMO ACCOUNT 4: BUILDING SOCIOTECHNICAL ALLIANCES FOR INCLUSIVE DEVELOPMENT (HERNÁN THOMAS, LUCAS BECERRA, AND PAULA JUAREZ)

Residents in the remote rural community came to the "local management desk" to discuss how to build on the fumigation project to produce a more permanent mechanism for accessing water that was not contaminated with arsenic. Attendees included local families, teachers from the school, officials from a national technology institute, and the STS researchers. The group had previously decided to make its decisions through a lottery-like system. Groups in four other rural areas of the province of Chaco included in the project had chosen raised hands, elected a representative, or appealed to ancestral criteria.

Hernán Thomas, Lucas Becerra, Paula Juarez, and other STS scholars from the National University of Quilmes, Argentina, had borrowed the concept of the local management desk from a government agency. But by reapplying it outside of urban settings as part of the DAPED (Right to Access to Goods: Water for Development) project, they added distinctive sociotechnical content to its organization and practices. The Quilmes team was seeking to generate "actual dynamics of local development" in especially poor regions to the north and to build a lab for the national "public-public consortium" that the STS scholars had worked for years to establish. The local management desk was one "sociotechnical alliance" among several the team had created.

Five years earlier, the relatively new national Ministry of Science, Technology, and Productive Innovation approached some of the Quilmes scholars for help developing "technological solutions" for "chief social issues." These included lack of access to drinking water, housing, and energy, as well as the high costs of medications and the prevalence of regional diseases that had no cure. Since completing a degree in science and technology policy, Thomas had been critical not only of linear images of technological determinism but also of such alternatives as appropriate technology, alternative technology, grassroots innovation, bottom of the pyramid, and social innovations. Although technological determinism ignored social dimensions, the relatively fixed social commitments in other theoretical models tended to produce short-term responses, aftereffects that might be worse than the initial problem, and problems in the planning of devices and systems to realize them.

The evolving Quilmes team accepted the invitation from the ministry as a challenge to shift its scholarship from the orthodox, safe exploration of "topics" to the targeted, risky investigation of "problems." Embracing problems did not mean directly seeking solutions, however. To do so would be to continue the long-established focus of supply-side, market-oriented governmental policies in science and technology. Rather, embracing problems meant moving beyond publishing critical analyses and informed discourse for academic audiences and working with "other social groups (e.g., policy makers, policy practitioners, social movement activists, and civil society

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entities)." It meant collaborating with such groups to figure out who would be the expected users of research results, and developing mechanisms to include them in both defining and addressing social and environmental problems. Building "technologies for social inclusion" thus required not only theorizing technological systems as sociotechnical in content but also adding new sociotechnical alliances to include expected users.

Can STS knowledge be "applicable," yet not "applied" (Kreimer and Thomas 2004; Thomas and Kreimer 2002)? How, asked the Quilmes team, can STS knowledge be taken up in actual deliberations involving science and technology? Thomas's theory of social technological systems adroitly positions the word "social" to achieve applicability. It means inclusive. That is, the technological systems it describes seek inclusivity. Non-STS listeners who encounter the theory experience no challenge to view all technological systems as sociotechnical in content all the time. For members of the Ministry of Science and Technology and National Institute of Agricultural Technology who tend to define technology in purely technical terms, the adjective "social" simply points them to develop technologies whose benefits include inclusivity. For the STS scholars and officials in the Ministry of Social Development involved in the water project, adding the adjective authorized their focus on the organizations and actors that must be created and added to enable a given water technology to come into being and serve its users.

Establishing the water project took five years because it required that much time to create the necessary sociotechnical alliance to fund and carry it out. The Quilmes team proposed that the science and technology ministry fund a public-public consortium co-organized by the social development ministry and the agricultural technology institute. But the S&T ministry had no authority to fund "social development" and the state bureaucracy lacked procedures for intragovernmental articulation. The water project ultimately came into being in significant part because a previously established sociotechnical alliance provided a "collaborative platform" for it. The Network of Technologies for Social Inclusion brought together public and private institutions committed to "strengthening and improving the capabilities of innovation and technological development for social inclusion." After filling a gap between the private and public sectors, the network persuaded the government to fill a gap within the public sector.

Thomas's theory of social technological systems came to serve as a "lighthouse" for the Quilmes Institute of Science and Technology Studies, leading researchers to expand their scholarship. New research projects included contributing to the development of public policies, which in turn reconfigured the masters and doctoral research of scholars in training. Also, the institute expanded its publication strategy beyond academic outlets, and it formulated and enacted a communications strategy "aimed at challenging political and social agents." In the process, both research and researchers experienced a "dynamic transformation." Not only did the "problem

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agenda, knowledge generation, and researcher concerns and activities" change, but so did "the very notion of what a researcher is." In our terms, by producing and sustaining sociotechnical alliances, Quilmes team members relocated their theoretical commitments to their making & doing work.

DEMO ACCOUNT 5: ADDING ISSUE PUBLICS (TORBEN JENSEN, ANDREAS BIRKBAK, ANDERS MADSEN, AND ANDERS MUNK)

Starting with the recognition that there is no such thing as a purely automated analysis, Torben Jensen, Andreas Birkbak, Anders Madsen, and Anders Munk work with "issue experts" to produce alternative visualizations of the data they analyze together. The group of differing, even opposed, "stakeholders" whom project organizers had identified and invited to participate may decide to delimit the view to a shorter period or to filter out actors who are relatively unconnected to other actors. The STS scholars are on the "constant lookout" for techniques to iterate quickly from one way of visualizing the data to another. Yet they have found through a range of individual empirical "experiments" that they cannot define themselves out of the process. Producing the next data visualization may take them minutes or hours, and they may even have to leave the room to generate a new poster-sized printout. Experiencing iterations of empowerment and loss of control strengthens their commitment to produce a "kind of ontological inquiry that works against universalistic and too-quick assumptions about the world." Yet they see danger in possibly becoming "merchants of multiplicity."

The authors harvest massive quantities of data from Twitter, Facebook, scientific articles, and other databases to help people involved in a debate, controversy, or future planning to identify what's at stake in an issue at hand, and for whom. The Danish Board of Technology had long organized citizen hearings on technoscientific issues, enrolling "trusted experts" to help produce the detailed handouts that initiate and guide discussions. The STS scholars harvested four hundred thousand tweets related to the Zika virus and then analyzed them through network graphs to identify the "issue publics" (Marres 2005) that had emerged through debates on Twitter. Results appeared on the handouts. Likewise, the scholars harvested Facebook data to help the local Aalborg municipality identify nine hundred different visions of possible school reform and the Royal Danish Theater to identify different ways of construing "authenticity" in self-defined cultural enterprises and productions. Another project drew data from scientific journal databases and food-related Instagram posts to demonstrate a "surprisingly fragmented discursive landscape" in research about obesity.

Collaborating with diverse participants in debates or controversies provides the scholars with a surprising sense of empowerment qua STS researchers. Their collaborators attribute significant power to the digital maps, once they understand how to interpret them. They tend to describe the visualizations as the "actual, databased facts"

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about the field as opposed to their own representations as participants within the field. Such judgments persist even as the STS experimenters stress "their constructed nature, the uncertainty of data, and the dangers of reading too much into them." They maintain that the visualizations shape questions, not answers. Yet the visual products tend to "travel much faster to other settings when wrapped up as facts."

The recognition of empowerment iterates with a sense of loss of control. Producing maps positions the STS scholars as a kind of mediator. They cannot claim to be knowledge authorities on the field in question. Producing maps that get to become actual or factual also entails detaching the scholars who figured out how to work with the software to extract persuasive visualizations from mass quantities of data. And then the external partners further distance themselves from the experimenters by carrying the products away to use on their own. The STS scholars get left behind.

A key example is the politicians and municipal leaders whose vision of school reform faced opposition from the teachers' union. The union was arguing that the reform would negatively affect teachers and their work. When the visualization "suggested that not all teachers were united in their critique," the leaders used it to destabilize the opposition by showing discord within its ranks. Indeed, the authors report that they "constantly" encounter potential collaborators who have a stake in "producing particular kinds of multiplicity."

What ethical responsibilities are borne by STS scholars whose products leave them behind and travel sufficiently to become true or real in the field of study and participation? These scholars argue that their products come with ethical commitments. The collection of practices that add up to "participatory data design" carries with them a commitment to multiplicity. Accordingly, they are reluctant to seek contracts from powerful stakeholders who want them to perform a "targeted deconstruction operation" on a particular issue public, making multiplicity visible in order to subordinate others. To ensure that the municipal leaders would not easily stabilize one of nine hundred visions via the specific visualization they supported, the experimenters insisted that all the formulated visions remain publicly accessible online. Their commitment is to the multiplicity. They do STS by "setting in motion processes that collectively engage more actors with datafication as a means for ontological inquiry and building new things."

DEMO ACCOUNT 6: ADDING ACCOUNTABILITY TO THE COD (MAX LIBOIRON, EMILY SIMMONDS, EDWARD ALLEN, EMILY WELLS, JESSICA MELVIN, ALEX ZAHARA, CHARLES MATHER, AND ALL OUR TEACHERS)

The revised draft of this demo account left the fish off the list of authors. At a meeting to discuss putting the fish as first authors, lab members recounted cases in which assigning authorship had or would have the effect of committing violence against someone. At a previous meeting, they had identified the labor that went into the

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manuscript and the laborers who had contributed. All had agreed that the fish had contributed, by dying. But including fish as authors would ignore the uneven social locations and histories of contributors. There can be no parity between parties when one has died. Also, even if still alive, the fish would not acquire an obligation to the submitted manuscript that human lab members gain. Max Liboiron, Emily Simmonds, Edward Allen, Emily Wells, Jessica Melvin, Alex Zahara, and Charles Mather appear as authors because they chose to follow the "norms of science in which only humans are considered authors." The cod, hake, and char gain authorial credit as part of the larger heterogenous category of "All our teachers."

Contributors to the Civic Laboratory for Environmental Action Research (CLEAR) position themselves as marine scientists "committed to Western science and its ways of knowing." But they equally resist values that "undergird and reproduce the dominance of science over other forms of knowledge." Scientists, they maintain, always work within relations. Relations produce obligations, and obligations constitute ethics. And vice versa. Members of CLEAR commit to recognizing their "obligations to emplaced relations" by "enacting equity, reciprocity, or humility" in their research practices.

Lab members agree with other scientists that marine animals and humans are at risk from chemicals that are concentrated in plastics. These chemicals accumulate in the tissues of fish that ingest them and biomagnify through the food web. CLEAR stands out among research labs in a university setting by attending to obligations that accrue to their location in Newfoundland and Labrador, where "marine mammals, birds, and fish are a mainstay of diets for rural and Indigenous communities."

Because obligations "come from where we are from," lab members draw on their identities as feminists and anticolonialists and on their "Métis, Kablunangajuk, local settler, and come-from-away settler positions." The work of CLEAR seeks to expand "how fish are known in a university setting." Fish and their guts certainly serve as samples. They also contribute as "food, political citizens, and grandmothers."

Drawing on feminist STS helps lab members see how realities are constituted by relations and dispose themselves to seek accountability within "nonmasterful, enmeshed relations" that frame the laboratory work. Drawing on Indigenous thought adds the crucial insight that, by means of constituting realities, relations also constitute obligations. In the process of producing realities, a scientific laboratory also fulfills obligations or not. To make and do marine science via a feminist, anticolonialist scientific laboratory significantly expands the scope of the myriad obligations to which the lab must attend.

Members of CLEAR attend to such obligations through scripted protocols. The scripts range from sharing fish guts with a woman on the wharf, to gaining permission to dispose of guts as food rather than hazardous waste, to figuring out author order and citation strategies. Foregrounding obligation keeps lab members focused on local scales and specific actions because relations are "never in the abstract."

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At the same time, obligations are "sometimes at odds with one another." A scientific lab that recognizes its relations and seeks to fulfill its obligations must necessarily make compromises. Lab members dedicated to expanding how fish are known must "pick [their] way through the less-than-ideal landscape." Making compromises makes clear that relations, obligations, and ethics are "best enacted as synonymous." They merge epistemology with ontology, axiology, and standpoint. Research practices in CLEAR work out all simultaneously.

DEMO ACCOUNT 7: A CLINALYST INFRASTRUCTURE (JESSICA MESMAN AND KATHERINE CARROLL)

The breast surgeons found out that their workflows "were much more entangled" with those of the surgical pathologists in the lab "than they had realized before." As the surgeons analyzed video clips of pathologists evaluating specimens taken during surgical procedures while also managing multiple other specimens coming and going, they were amazed that "we do as well as we do" in collaborating to produce diagnoses of diseases such as breast cancer. The two groups participated in "video-reflexivity" sessions designed to make visible their strengths and identify pathways for improvement. In this case, the surgeons and pathologists developed a written template to better describe the orientation of the specimen in the patient's breast, something both needed. They also modified such other procedures as "developing a script for call-back, and requesting both the pathology and surgery staff [to give] verbal confirmation and verification of reports." In so doing, report STS scholars Jessica Mesman and Katherine Carroll, the two groups of physicians expanded their definition of team success by adding interprofessional communication to outputs from laboratory instruments. And they joined the STS scholars as "clinalysts" who catalyze insider knowledge by asking outsider questions and maintaining "a constant tension between critique, interpretation, analysis, questioning, and concluding." The changes happen fast, implemented within months.

Mesman and Carroll describe video-reflexive ethnography as a collaborative visual method to "understand, interpret, and optimize professionals' work practices." The camera serves as a key, central device. But only in relation to others. The STS scholars gain the permission of hospital practitioners to video them in agreed-on settings and situations. The scholars produce clips that isolate informal mundane routines and make them literally visible. They then facilitate the discussions that transform the routines into remarkable achievements of everyday work. As nurses, doctors, and other staff members watch the delivery of complex, dynamic practices, they see Grand Central Station, a "well-orchestrated symphony," or simply "value" in their own work and the work of others around them.

The dominant image of hospital evaluation and improvement emphasizes innovation. External consultants contract with hospital administration to deliver advice and

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models for change. Mesman and Carroll start off with such an external identity and role. But before the camera ever enters the hospital setting, the STS scholars meet and work with every potentially affected group to construct a new infrastructure that includes everyone. Typically, an internal advocate facilitates introductions and initial meetings. Tacit approval by all, including hospital administrators, leads to a formal internal research proposal and procedures for protecting the rights of human subjects. Everyone becomes a clinalyst in this added infrastructure, essential to its performance—STS scholars, observed workers, camera, and so on. Mesman and Carroll call the preparatory work both "foundational" and, following John Law, "deeply messy."

In the new infrastructure, the STS scholars neither remain outsiders nor become insiders. They become "alongsiders," a role that confronts challenging issues of accountability and professional vulnerability. In a study of how an emergency department hands off urgent cases to surgery, the STS scholars don blue surgery scrubs so they do not need to seek permission every time they want to cross the threshold between the two departments. The scrubs made patients "think we belonged to the hospital staff" and sometimes made others in scrubs visibly wonder if the STS scholar was "one of us" or not. And the scholars themselves felt "angst" over not having enough time to form genuine relationships with people to begin to be considered as insiders," despite their seemingly moving from outside to inside. Also, their frequent presence "on location" meant that the scholars had made themselves available not only for "praise" and "advice" from participants but also "direct criticism." What responsibilities do they acquire in the unstable identity of alongsider? In building the clinalyst infrastructure, they join with hospital staff to produce the "shared framework" that pursues "collaboration and quality and safety in health care." But what comes along with their "affective enrollment"? When, they ask, does "giving in and being flexible" in responding to requests and challenges "become a threat to one's ambitions" as an STS scholar?

The emergent clinalyst infrastructure can persist. It can become robust. During a study of patient safety in neonatal intensive care, Mesman could not be present for reflexivity meetings. At first, the meetings were canceled. Then other members of the video team took it on themselves to continue. They selected the footage, organized and chaired the meetings, and taped the discussion. The new clinalysts were able to carry on documenting how they go about "doing safety" and identifying what new steps they might take to do safety better. The STS scholars learned that they could design their own exit into the clinalyst infrastructure to the extent that other participants would be willing and able to "maintain a constant tension between critique, interpretation, analysis, questioning, and concluding." In this way, their approach to empiricizing as alongsiders what it meant to improve quality and safety in health care also resulted in a situation where clinalysts equally became alongsiders of STS scholarly practices, helping all figure out how STS infrastructures can remain alive at a larger distance from STS scholars.

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DEMO ACCOUNT 8: ATTACHING RADICAL ALTERITY (NICHOLAS SHAPIRO)

One of the first people lifted by the balloon was an environmental activist who lived beside a sprawling petrochemical plant outside of Buenos Aires. Elsewhere, environmental justice advocates invoke the "well-publicized quasi-plausible future that the project advocates" by tethering solar balloons at their protests as rallying points. The Aerocene serves as a platform for social movement action that calls attention to and resists chemical violence. But its ethical doings go beyond documenting harms and demanding policy changes. To Nick Shapiro, a project collaborator, the aerosolar balloon materially cultivates not just incremental reforms but an immaterial alternate, the "ethos, altered subjectivity, and desires" of a radical alterity.

Shapiro accepted an invitation to join a collaborative project aimed at realizing aerosolar balloon travel—that is, travel in hot air balloons filled with normal air and gaining loft through the heat of the sun—as a viable means of global mobility. Meteorologist collaborators built a web platform for plotting when to fly and which winds at which altitudes to catch in order to reach a particular destination. The idea is to make visible a "transit infrastructure" that is latent in everyday ecologies. The Aerocene engages that infrastructure without expecting to master or control the "extra-human environment" that constitutes and animates it. Quite the contrary. To its organizers, the Aerocene is about "calculated submission" to that environment.

Contributors are making and doing different things as they design the balloon, build circuit boards for the positioning and data relay system, experiment with infrasound sensors, model the elemental variables of flight, calculate soar flux, encourage public participation, and so on. Indeed, with the project led by an artist, the work of "developing infrastructure, technology, and community" can take "second seat" to representations in art installations. In other words, tensions arise in partially competing visions of how to simultaneously build and imagine the world differently. Shapiro has led balloon launches in Antarctica and Idaho, supplied and advised on the suspension of air quality sensors from the balloon, codeveloped a lending library and data-sharing protocol, guided open licensing decisions, and written short pieces about the project. But he "wriggle[s]" out of a charge to "discern what scientific payloads would be most useful to environmental justice advocates" because his contributions to the project aim at something other than civic technoscience.

Shapiro joins other scholars in critiquing the "hydrocarbon and intellectual property infrastructures that envelop our world." Yet rather than endorse reformists' efforts to decarbonize the grid and spawn a world of batteries and short-lived solar panels, he insists on grappling with the "assumptions, imaginaries, extractive logics, asymmetrical financial benefits, regimes of consumption, and traditions of ecological mastery" that emerged with hydrocarbon engineering. That is to say, his critical analysis motivates intervention into the "presuppositions" that frame the problem to be solved. What does it take, he asks, to "mak[e] harms *un*necessary"?

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In this framing, the Aerocene is no more "escapist fantasy" than believing that technocratic reformism that accepts dominant assumptions about current infrastructures will also somehow change them. The Aerocene he is involved in is a "paradigm-shifting" project with "serious environmental justice chops." Accordingly, Shapiro judges his most important contributions to be speaking publicly about the project, to show how it differs from dominant approaches to detoxification. To him, the Aerocene "carve[s] out imaginative space" in a way that cannot be achieved by "polishing the status quo."

Wriggling out of the charge to produce data aimed at environmental justice also produced important learning. The pursuit of radical alterity necessarily includes incrementalism. "Neither is superior." When standing alone, incrementalism certainly risks dissolving into reformism that accepts the enclosures of the present. So, to Shapiro, the ethical doings in the Aerocene project become challenges to build "productive friction" between its incremental moves and its alter-engineering subjectivity, to ensure that incrementalism remains attached to radical alterity. He sees in the project opportunities to help effect "syncretic methods of environmental change," thereby positioning his practices of STS scholarship right at the intersection of the imaginative and the messy.

DEMO ACCOUNT 9: ANIMATING THE THIRD SPACE OF AID KNOWLEDGE (TEUN ZUIDERENT-JERAK)

A group of guideline developers, the Working Group on Appraising and Including Different (AID) Knowledge, has come together at an international conference to discuss how best to appraise and include knowledge in guideline recommendations that does not come from randomized controlled trials (RCTs). Zuiderent-Jerak is chairing as cofounder of the group. He tries to focus their work on the development of appraisal methods for knowledges in the plural, having been convinced that challenging the epistemological shortcomings of evidence-based medicine (EBM) just repeats stale, stereotypical accounts of epidemiology. Epidemiologists, he maintains, were never as epistemologically naïve as their critics depict them. Did not the founders of EBM themselves indicate, contrary to sociological accusations, that their project was *not* about the absolute supremacy of the RCT? Are knowledge infrastructures, then, not a desirable locus for changing the politics of knowledge in EBM? Could focusing on them perhaps provide a passage that bypasses tired yet sticky debates that position epidemiology and the so-called human sciences on opposite epistemological shores with nothing but thick layers of ice between them?

Zuiderent-Jerak borrows the metaphor, with the help of Steve Brown (2002), from Michel Serres (1983), who proposes that traveling between the shores of the so-called natural and human sciences compares to "traveling the Northwest Passage." Traveling between the "messy coastlines in northern Canada that connect the Atlantic and Pacific Oceans," which are variable, fractal, and "an adventure to be had," compares

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to navigating between the shores of sociology and EBM. Traveling requires occupying a "third space"—a space of transformation that lies between. When traveling this third space to *found* AID Knowledge together with leading guideline developers, it proved crucial to undo the critique of the epistemological narrowness of EBM. That passage had been frozen for too long. Now that AID Knowledge has itself become a third space between EBM and the human sciences, Zuiderent-Jerak argues in the working group, the focus on knowledge appraisal infrastructures rather than epistemology should remain. It is a nice try, but the guideline developers are not convinced.

One of them suggests that it will be crucial to nominate important alternatives for what Ian Hacking calls "frequentist reasoning." Without challenging the dominance of the "epistemological assumption that the more we observe a (controlled) phenomenon, the better the knowledge of it we have," all appraisal methods for other knowledges will, the working group member fears, leave them looking second best. The politics of knowledge infrastructures cannot be disentangled from epistemology. Providing a sense of alternative "styles of reasoning" becomes a crucial next step. Otherwise "appraisal infrastructures for all other knowledges will . . . continue to look inherently less reliable and knowledge inclusion will be on unequal terms, because other knowledges will have the wrong frequentist measures applied to them." Zuiderent-Jerak learns that, what looked like a passage to him, others in AID Knowledge see as a "dead end" that would leave them "stranded at the shore of current EBM and its frequentist reasoning." Better to test how thick the epistemological ice is. They jointly author an article on how different knowledges require different styles of reasoning (Wieringa et al. 2018). It makes most of them, including Zuiderent-Jerak, read up on philosophy of science.

STS insights about decentering epistemology had been crucial when founding this working group as a third space within an international association for guideline development. Yet once that version of the STS insight had done its work, it found itself challenged within this third space. The reminder "of the entwined nature of ontology and epistemology" shows how STS knowledges became part of the "perpetual translation" that comes with traveling the Northwest Passage and occupying "spaces of transformation," as Serres puts it. To explore this "oscillation between the shores" STS may be particularly well placed. The "nomadic nature and elasticity of STS" with its scholars "inhabiting an overwhelming range of academic departments" is sometimes seen as a risk to the future of the field. The myriad of interlocutors it produces, however, may be a main source of vitality.

DEMO ACCOUNT 10: INFLECTING DOMINANT KNOWLEDGE PRACTICES WITH OTHERS (GARY DOWNEY)

The tangible outcome of the teleconference was but three sentences in a 750-word position statement promoting active learning in engineering education. Gary Downey

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edited them to critically engage and help retheorize a pervasive distinction in engineering that demarcates technical knowledge from social knowledge. His demo account explores what is at stake when expressions of STS knowledge confront a dominant knowledge form in technoscience. Following the travel of STS knowledge flips its framing and priorities, he says, prompting its examination from "outside [the field] in as well as from the inside out." Downey elaborates practices of "critical participation," defined as "developing, expressing, and attaching sociotechnical practices to engage and inflect a dominant knowledge form in science and technology without necessarily dismantling or wholly replacing it, . . . produc[ing] flows of sociotechnical learning and reflexive sociotechnical learning." Going into the teleconference, he was interested in learning if the experiment might add a new pathway to inflect core practices of engineering calculation. Afterward, he found it important to reframe the heart of his own project.

Downey had been contacted by advocates of active learning who were frustrated with the resistance they had encountered from engineering faculty. Concluding that engineering education has a cultural problem, they wanted to know how they could go about changing the culture. Downey's critical STS accounts had found limitations in educational practices that claim to produce engineers with technical knowledge only. But while the activist educators pictured a cultural problem surrounding engineering, Downey located a problem precisely within the knowledge core of the engineering curriculum.

He draws on this interaction to examine three scholarly issues that critical participation in dominant knowledge practices must confront. The first is to theorize the production and persistence of knowledge dominance in ways that open it to engagement from traveling practices of sociotechnical knowledge. By theorizing culture as "dominant images," Downey frames the demarcation between technical and social in engineering as a valuation built into the relations that produce curricular infrastructures and connect them to one another over time. The second involves following dominant attachments of knowledge to personhood, where the category of persons can extend to nonhumans, and problems of personhood emerge as relations within an entity. Downey briefly explores how engineers encounter and respond to challenges of personhood they experience in the engineering demarcation between technical and social. The third involves translating sociotechnical findings into sociotechnical techniques, devices, infrastructures, and selves, and attaching them to the field, often as gifts. To the extent they express STS knowledge in ways that inflect, or interrupt persistence in, dominant knowledge practices, he describes them as "STS practitioners." In the teleconference, Downey adapted a longer-term pedagogical project in infrastructuring and selving: a course designed to activate STS findings about engineering knowledge and personhood into an expanded image of engineering practice and persons that positions culture within both.

Downey suggested that the educators engage resistance by first trying to understand it. Dominant images of engineers and engineering have certainly changed

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and will change again, but that doesn't make it easy to effect change. Might they recruit faculty and students to join them in reflecting on the knowledge, identities, and commitments they gained through existing learning techniques and then explore how active learning might challenge or reframe those outcomes? At stake in their project, he said, are core questions about what counts as engineering knowledge, what it means to an engineer, and what engineers seek to accomplish through engineering. The educators expressed enthusiasm about positioning culture within engineering as a step to promote active learning. The draft statement that arrived, however, reinscribed the demarcation between technical and social, presenting the "content" of engineering as located "within an established culture." Downey saw in the draft statement a potential entry point through the concept of mind-sets. He followed it in order to test whether or not that pathway, too, left space for the activist educators to reinscribe what has become a remarkably resilient demarcation.

Yet as he reflected on how to further engage their project, Downey realized he had also assigned himself the responsibility to examine how his own project might be construed as enacting practices from theirs. Engaged STS can produce an "epistemic coalition" of projects, he finds, that travel together and can learn from one another. Critique alone can put scholars in competition with one another in zero-sum games of visibility and status, postponing or omitting attention to the practices and problematics of knowledge travel. Scholarly projects that enact critical participation certainly compete for position and resources but, for one to win, others do not have to lose. Recognizing coalition as collaboration becomes a sign of epistemic strength because it "signals a vision of the field as a whole."

KNOWLEDGE EXPRESSION AND TRAVEL AS SENSIBILITY WORK

Adding expression and travel activates STS scholarship by refiguring its problem spaces (Zuiderent-Jerak 2015) and expanding its scale (Downey 2009). The scholarship of making & doing includes but becomes more than outreach, which pictures scholars diffusing knowledge. STS making & doing includes but becomes more than teaching, to the extent that teaching pictures scholars as transferring knowledge. The scholarship of STS making & doing challenges what some academic fields call translational research, which looks to apply findings and discoveries from basic inquiry. Projects in STS making & doing stand out by expanding the practices of STS scholarship, responding to frictions by experimenting with techniques, devices, infrastructures, and selves that they produce and attach to specific empirical settings. The scholarship of STS making & doing is sensibility work.

These narrative demonstrations and interpretive accounts of STS making & doing are producing knowledge about STS initiatives to express knowledge as sensibilities and attach them to the field. Such practices are STS practices. Questions about which STS lessons genuinely make it into empirical arenas, how they get there, and how they are transformed by the journey are fundamental ones. Through projects that genuinely

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and thoroughly interrogate relations between knowledge expression and travel, STS scholarship is able to explore fully what it can mean to turn STS lessons onto STS work.

This book gives reasons for optimism. Questions about the relation between STS scholarship and societal challenges involving science and technology have often taken the form of claims about the impact we could or should be making and laments about the absence of STS academic contributions in popular debates and deliberations. Privileging academic theory and hoped-for outcomes, such laments have focused their gaze too narrowly. They miss all the ongoing scholarship that activates STS, making and doing STS sensibilities through nonlinear forms of knowledge expression and travel.

NOTES

1. The practices are too numerous to discuss here. Some that we have found instructive include recognizing captivity (Scott, Richards, and Martin 1990), situating one's knowledge (Haraway 1991), taking account of standpoint (Harding 1986), doing ontology as multiple (Mol 1999), adding concern (Latour 2004), linking ethics and ontology to epistemology (Barad 2007), keeping normativities from damaging scholarship (Lynch 2009), attending to undone science (Frickel et al. 2010), and adding care (Puig de la Bellacasa 2011).

2. The contributors to demo accounts 1 and 4 shared some examples of publications for other audiences. See Jobin, Chen, and Lin (2018); Lin, Chen, and Jobin (2018); and Xie Peiqi 謝珮琪 (2018). See also Drovetto (2018); Juarez (2019); and Piscetta (2020).

3. We prefer to use the ampersand (&) rather than the word "and" to describe making & doing. The ampersand makes clear that "making" and "doing" are connected activities.

4. See, for the STS Making & Doing program, Society for Social Studies of Science (2021). See also Wylie (2018), a "call to action" that extends the presentation of research findings to include STS making & doing.

5. See the coda to this volume for further discussion of this point.

6. During the writing process, we lost one contribution that engages empirical arenas in the Global South. The ten projects include one each in Argentina, Taiwan, Canada, and Denmark; two in the United States; one among Austria, the United Kingdom, and a multitude of countries in Africa and Asia; one between the United States and Latin America; one between the Netherlands and Australia; and one in an international network that includes members from Europe, the Americas, and Australia.

7. We have watched as research examining the social, cultural, and political dimensions of science, technology, and medicine in disciplinary terms has expanded greatly in sociology, anthropology, political science, and other fields. Insisting on simultaneous attention to both knowledge and social dimensions helps to ensure that the projects are contributing to interdisciplinary spaces occupied by STS scholarship

8. We thank Joseph Dumit for proposing an early version of this practice for the 1993 advanced seminar, Cyborg Anthropology, at the School of American Research, Santa Fe, New Mexico (Downey and Dumit 1998). Gary has further experimented with the format.

9. See, for example, Sally Wyatt's challenge regarding technological determinism, which, though declared "dead" within STS, is a prevailing dominant image in many settings (Wyatt 2008).

10. See, for example, the 2010 theme issue "Embodying STS: Identity, Narrative, and the Interdisciplinary Body," in *Science as Culture*, edited by Benjamin Cohen and Wyatt Galusky (Cohen and Galusky 2010, 1–122).

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11. Note that Scott, Richards, and Martin (1990, 477) presented in first person their case studies of STS knowledge being captured by controversy. They said it was "for convenience," a justification that avoided direct challenge by minimizing its significance. Still, as Atsushi Akera wrote in a January 16, 2020 email discussion of Gary's work, an account that is "deeply personal" can also be "a little hard to read!" (cited with permission).

12. And by revealing the person in the project, they also compel attention to the boundary work that attempts to detach knowledge production from personhood in safe scholarship.

13. The coda to this volume argues for integrating demo accounts of STS making & doing into the infrastructures of publication for STS scholarship.

14. See also Jensen, Birkbak, Madsen, and Munk, demo account 5 in this volume.

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1

STS ON THE STREET AND AT THE COURT

Interlocutors in the Taiwan RCA Collective Occupational Disease Lawsuit

Yi-Ping Lin and Hsin-Hsing Chen

Yi-Ping Lin [林宜平] clearly remembers the day she first attended the advisory group meeting at the Legal Aid Foundation and the day she first stepped into the courtroom. She had just moved to the newly founded Institute for Science, Technology and Society at National Yang-Ming University from her previous job at the National Taiwan University (NTU) College of Public Health. From her earlier participation in public health studies of the RCA (Radio Corporation of America) case, she had published an article criticizing RCA health effect studies from a feminist perspective (Lin 2006). Hsin-Hsing Chen [陳信行] and his colleague Cheng-Liang Chen [陳政亮], both active in the labor movement and the burgeoning STS community in Taiwan, went to Yi-Ping's office to invite her into the academic support work for RCA workers. Later joined by Paul Jobin, a French sociologist working in Taiwan, they became the core of the RCA workers' advisory group. Since 2005, RCA's Taiwanese workers had been suing their former employer and its parent companies, seeking compensation for cancer and other serious diseases they believed to have been caused by their exposure to toxic chemicals at the workplace during the erstwhile global electronic giant's operation in Taiwan between 1970 and 1992. After years of procedural hurdles, the Taipei District Court finally started hearings on substantial matters of the case in September 2009.

Hsin-Hsing was curious about what kinds of material Yi-Ping had that could be useful for the workers' case. It turned out to be a lot. Yi-Ping pulled out two boxes from under her desk. One contained a complete photocopied collection of the magazine *RCA Family* [*RCA 家園*], which was published by RCA Taiwan and circulated among its workforce during its operation from 1970 to 1992. Another included a complete collection of reports of epidemiological and toxicological studies commissioned by Taiwan's Ministry of Labor and its Environmental Protection Agency and done by the NTU College of Public Health and other institutions. Perhaps most

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importantly, Yi-Ping knew many public health and environmental science experts who would love to help but didn't know how to start.

Active in the environmental and labor movement since his college days, Hsin-Hsing practically grew up in the Taiwanese social movements of the 1980s. He was familiar with the context for why socially concerned scientists, such as Yi-Ping's friends in public health, felt frustrated. Resistance toward technocratic authorities is an integral part of contemporary social movements in Taiwan, and scientific-sounding words are often regarded by protesters on the street as on the side of the authorities, hence mistrusted. Professionals might be welcomed to support one social cause or another with their prestige, but they often found it more difficult to contribute directly with their scientific knowledge.

It was no coincidence that the first effective opposition party founded during Taiwan's three-decade-long martial law regime chose green as its party color. It was 1986. The Chernobyl disaster had just taken place in the Soviet Union. In the wake of the disaster, grassroots antipollution protests erupting in Taiwan, including an antinuclear campaign that continues to this day, often featured farmers and workers questioning the technocratic decision-making in the state and calling out the condescending attitude of the technocrats toward the great unwashed. Scientific knowledge lives at the center of a democratic sensibility emerging at this conjunction.[1] On one side of the barricade, there was the state and a growing rank of highly educated technocrats who believed they possessed the scientific truth and technological superiority. On the other side were common folk who felt there was definitely something wrong with the environment in which they lived and worked but lacked the means to articulate it.

Despite the purported ideological opposition between the right-wing regime of Taiwan and its communist counterparts in the world during the Cold War, they share the characteristics of strong technocratic developmental states. Inviting high-tech companies such as RCA to invest in the country and use the cheap and docile workforce for labor-intensive export-processing industries, Taiwan became one of the conspicuous newly industrialized economies alongside South Korea, Singapore, and Hong Kong. Indeed, many of the central figures in Taiwan's famed semiconductor industry today started their careers from a collaborative training program sponsored by the Taiwanese government and RCA in the 1970s. Advanced technological companies like RCA were not supposed to poison their employees, according to the mind-set prevailing during Taiwan's decades of rapid economic growth.

In this context, former employees suing RCA for their occupational diseases also indict this piece of recent history in our country. Moreover, since the developmental model of export-oriented industrialization has become so prevalent in the post–Cold War world, companies doing business as RCA did in Taiwan—for example, Foxconn, Samsung, or Huawei—may very well be exposing workers in far corners of the world to the same hazards as the Taiwanese workers had endured. Thus, the campaign

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against RCA is, at the same time, a call to attend to one of the pressing matters facing workers in high-tech sectors today.

In order to sue RCA, however, the workers needed scientific expertise to translate their personal experiences into observable collective facts, and they needed legal expertise to articulate the facts. We had to find a way to bring the public health researchers that Yi-Ping had been working with into the workers' campaign and help them work with lawyers, activists, and the victims. Otherwise, there would be no legal case to fight at all.

Former RCA employees had been organizing and campaigning since 1998, after it was disclosed that the company had been illegally dumping hazardous organic solvents on the plant site during its operation in Taiwan from 1970 to 1992. Former employees and their families held many street protests to compel the government to do something about the alarmingly high rate of cancer found among fellow workers. Hsin-Hsing helped out in this wave of organizing, because the major organizers of the workers had been his fellow activists back in the 1980s.

The newly democratized state did want to do something. However, RCA claimed that all their operational records had been destroyed by a fire after the plant closure, and the government said it could do little without direct evidence of whatever had gone wrong with RCA. To have their grievances heard and redressed, RCA workers could not rely solely on street protests to win over public opinion and demand political will from the administrative branch of government. The judicial system, itself undergoing constant reforms since democratization, thus became the focal point of the RCA workers' campaign.[2]

The RCA workers' collective civil lawsuit against their former employer and its foreign parent companies was eventually taken over in 2005 by the Legal Aid Foundation, an independent public institution established the previous year in response to a long-standing judicial reform movement. Volunteer lawyers representing the workers faced a daunting task. This was the first collective civil lawsuit in the country, and every step would establish legal precedent. Furthermore, the lawyers faced complex and uncertain scientific evidence. It takes the craft of STSers to make the scientists and lawyers talk to and understand each other and work together to make coherent arguments. STSers, after all, have been explicitly trying to cross academic disciplinary boundaries in their inquiries for decades—from philosophy of technology to ethnography in the laboratory—and there is a whole body of accumulated experience on how this boundary crossing works or fails to work. The advisory group meeting attended by the lawyers, plaintiffs, activists, and academic advisors, including Hsin-Hsing and Yi-Ping, became the place for collective struggles to achieve mutual understanding. Since they started going to the meetings in 2009, reading and discussing scientific papers with lawyers, and sitting in the spectator seats during the RCA trial have become a shared memory of Yi-Ping, Hsin-Hsing, and the STS community in Taiwan (H.-H. Chen 2011a; Lin 2018).

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Even after a partial victory for the workers at the Supreme Court in August 2018, trials on this most science-intensive lawsuit in the judicial history of Taiwan still continue into the tenth year, because a portion of the case was remanded back to the high court for a retrial. The second high court in March 2020, however, was a major setback; only twenty-four victims were compensated. The case was moved into the Supreme Court once again. Meanwhile, after the first district court victory of the workers in 2015, a second group of more than 1,100 plaintiffs filed another collective lawsuit. Taipei District Court has found in favor of the workers again and awarded another record-high compensation of 2.3 billion Taiwan dollars to the collective of 1,115 plaintiffs.[3] The volunteer work of Taiwanese STSers continues as interlocutors among scientific witnesses, lawyers, activists, and workers.

A COMMUNITY AFFAIR

The first time Yi-Ping sat down in court in 2009, the very first witness in the case was being heard. Former RCA worker Hwang Chun-Tiao (Ah-Tiao) [黃春窕(阿窕)] was undergoing cross-examination at the Taipei District Court. It was Yi-Ping's first time stepping into a courthouse. She couldn't tell the difference between criminal and civil courts and immediately got lost inside the building. When she entered the courtroom, the defense lawyer for RCA was asking Ah-Tiao at what age her grandmother and grandfather had died and their cause of death. Yi-Ping knew that although the lawsuit would likely take a long time, the company lawyers were asking the wrong questions right from the start.

Ah-Tiao was a dream witness for the workers' case. Her father, mother, grandfathers, and grandmothers all had lived to nearly a hundred years of age, and none of them ever had cancer. She did not smoke or drink alcohol. When the presiding judge asked her why she thought her nasopharynx cancer was related to her work at RCA, she replied that when she worked on the wave soldering machine, the soldering pan emitted a pungent smell. She often got a nosebleed when she opened the door of the machine and smelled the sharp odor. So when she was diagnosed with nasopharynx cancer, she immediately thought about her experience on the RCA shop floor. Ah-Tiao spoke very slowly. Radiological therapy on her cancer had made it difficult for her to speak clearly. Even so, it was dead silent in the courtroom when she spoke.

Yi-Ping wiped her tears away and, in that moment, decided to stay with the victims and keep sitting in at the court sessions. The lawsuit would last a long time. Yi-Ping and Hsin-Hsing rarely missed a court session.

Regular attendees of the court sessions included the RCA workers; occupational health and safety activists from the Taiwan Association for Victims of Occupational Injury (TAVOI), who had been helping to organize the campaign since 1998; and students from STS, public health, sociology, law, and social transformation studies. Court observation became part of many professors' syllabi after the trial began in

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2009. Where else can you see science, law, and society engage with each other in the same room?

You cannot take pictures or record sounds inside the courtroom. Although the court always reserves dozens of seats for the media, the RCA case has been going on for so long that it is no longer news. Hardly any reporters have appeared to watch the court sessions in all these years, except for the brief moments of final debates and verdicts. So there has been no way to see through the media how the litigation is going. The only way to see the progress of the case is to go to the courthouse and watch the duel of scientific arguments unfold in slow motion. Thus, we encourage students to attend the sessions. Sociology students from Tung-Hai University in Taichung even hire a bus and come to the court sessions en masse.

Reactions to the proceedings vary greatly from one STSer to another. All are genuinely curious about people and things inside the courtroom. Some complain that the court clerk types too slowly in order to slow down the proceedings. Others are curious about how and when PowerPoint slides became integrated into court proceedings. Still others have started to research why there is a permanent seat for a translator in the court settings.[4]

The Chinese-language STS journal *Taiwanese Journal for Studies of Science, Technology and Society* (*STM*) published a special issue (number 12) on the RCA controversy in 2011. (C.-L. Chen 2011; H.-H. Chen 2011b; Jobin and Tseng 2011; Lin 2011). Since the journal's founding in 2001, this is the only issue that sold out all printed copies. Almost every academic and student volunteer for the RCA case obtained a copy of it. It even made its way onto the defense lawyers' desk in the courtroom. After the final debate of the district court trial in 2014, *STM* also published in its "Issues and Discussion" section a series of short articles based on court observations of the RCA trial.

After every session, a group photograph is taken in front of the courthouse. The RCA workers, together with the lawyers, TAVOI organizers, academics, student volunteers, and other supporters stand together and take a snapshot. From the cold of winter to the heat of summer and back to winter again, and from the Taipei District Court to the Taiwan High Court to the Supreme Court and back to the district court (with the second group of plaintiffs). There are enough of these courthouse snapshots to make an impressive collage or an entire photo exhibition.

In addition to attending proceedings and writing articles, STSers in Taiwan have also held press conferences, published op-ed pieces, and done other more "regular" interventions of the sort that intellectuals usually do regarding this or that social event. Working with TAVOI, some STS scholars helped organize a collaborative project that led to the book *Voices Refuse to Be Forgotten*, an oral history of Taiwan RCA workers (TAVOI and MAA 2013). This book won a Golden Tripod Award from the Ministry of Culture in 2014 for best nonfiction book. The documentary *Delayed Justice: The RCA Lawsuit*, funded by Taiwan's Ministry of Science and Technology and

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with active participation of several members of the Taiwan STS community, won an STS Making and Doing Award from the Society for Social Studies of Science and an award from the Taipei Labor Film Festival in 2018. The eight-episode documentary won the 2019 Golden Bell Award for best science documentary TV program. STS scholar Harry Wu [吳易叡], himself a musician on the side, wrote the song "Springtime" for RCA workers prior to the final 2014 debate at the Taipei District Court. Faculty and students at National Yang-Ming University, NTU, and Chang Gung University rehearsed the song and performed it that day as a chorus in front of the courthouse. This community has many talents.

COMMENTATOR OF A SLOW-MOTION BALLGAME

"Attorney Lin has pitched the ball! Let's see how it goes!" yelled Hsin-Hsing, sitting with dozens of former RCA workers in the basement cafeteria of Taiwan High Court. "The lawyers and advisors prepared this 'ball' two weeks ago," he went on to explain. Epidemiological questions in the cross-examination of an expert witness at court were sent flying like a ball in a game.

The cafeteria was an ad hoc arrangement made for this most unusual case. In most cases, few people would sit through those long and tedious court sessions as spectators. The main courtrooms are too small to fit even a portion of the more than five hundred plaintiffs. But the RCA case became an exception beginning with the hearing on substantial matters at the Taipei District Court in September 2009. Many plaintiffs insisted on being present, coming to the court and sitting patiently for hours through the sessions. They kept doing this even after both sides appealed to the high court. The high court administration decided to accommodate them. It designated the cafeteria as an extension courtroom and let the former workers and families watch the court proceedings through live streaming.

As a rule, speaking from the audience at court is strictly forbidden, and the extension courtroom is no exception. But the bailiffs of the high court had seen these well-behaved aunties and uncles so many times that they didn't bother to shush people anymore. Also, they recognized that the "commentators" were helping the former workers and families to understand what was going on. Cross-examination of expert witnesses was especially like ballgames, with lawyers of the opposing side throwing questions and expert witnesses trying not to give answers that would make them look ignorant, deliberately biased, or otherwise untrustworthy.

The gist of the "game" was to make these Q&As clearly intelligible to the panel of judges, whether the topic was environmental engineering, epidemiology, toxicology, health risk assessment, or other scientific issues concerning how industrial chemicals affect human health. If one side confused the judges by using too much scientific jargon, that side risked losing the judges' "*intime conviction*" and thus the case.[5] Explaining what the "ball" was to the plaintiffs in the basement cafeteria became,

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therefore, an essential aspect of the STSers' work in this collective litigation. Beyond their expertise in law, judges were, after all, as much laypersons as the RCA workers, activists, and volunteer lawyers with respect to the scientific evidence. If, by working with the volunteer scientists and lawyers in our meticulous preparation for the court sessions, STSers like Hsin-Hsing and Yi-Ping could help the workers understand the debate, surely the workers' lawyers could make the judges understand and feel the presence of knowledgeable plaintiffs at the same time.

Unfamiliar scientific content is not the only reason a commentator is needed to help viewers understand. The excruciatingly slow pace of the typical civil law proceeding effectively decreases any dramatic element in the trial and makes the court proceeding opaque even while it is open to the public to watch. Although it takes only a split second to tell whether an actual ball in a game scores or not, it usually takes more than half an hour in a typical cross-examination in the RCA trial. And it requires a time-lapse camera, or a commentator, to make the dynamics visible to people who are not familiar with the scientific and legal issues contested at court (H.-H. Chen 2014; Merryman and Pérez-Perdomo 2007).

After Hsin-Hsing yelled that day that the attorney had pitched the ball, he took some time to explain what the ball was this time. Inside the courtroom, during the thirty minutes or so after the plaintiffs' lawyer asked a question, the witness might ask the lawyer to repeat the question, the defense lawyer might object, the presiding judge would quiet the crowd and ask all to remain calm, and so on. Then the expert witness would carefully read paragraphs from a journal article (usually in English, with Chinese translation) or other reference material that the lawyers had presented as appendixes to the question, give a partial answer to the question, complain that the translation was inaccurate, give another partial answer, and so on. And the presiding judge would negotiate language with lawyers for both parties and the witness her- or himself and then dictate an answer that was worded to the satisfaction of all parties. Last, the court clerk would type the dictated answer into the court record. Now it became official.

On this day, the commentator in the basement cafeteria announced that the witness had been cornered and had given a bad answer. The response was similar to what we had anticipated two weeks earlier when we helped the plaintiffs' lawyers write this set of questions in long preparatory meetings over the weekend. And then, the commentator shouted, "Score!" The audience cheered, briefly, and then returned to their good manners and patient watching.

CATCHER IN THE OUTFIELD

While Hsin-Hsing was playing the commentator role in the basement cafeteria cum extension courtroom, Yi-Ping was sitting in a corner of the main courtroom, feeling like a baseball fan on the outfield grandstand with a glove on her hand, waiting to catch a foul ball coming her way. But instead of a glove, she was holding a

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smartphone, texting back and forth with the workers' lawyers at the bar. Sometimes there would be another volunteer sitting in front of a computer in the NTU College of Public Health building and with ScienceDirect or other scientific literature databases on-screen, ready to do a search on real-time demand from Yi-Ping.

The expert witness sitting in the dock that particular day was Dr. Pei-Fung L. Hurst [劉碧芳], one of the high-priced expert witnesses from the United States retained by RCA. She is a Taiwanese American with a joint PhD in epidemiology and virology. Formerly employed by the US Environmental Protection Agency, she was now working for an environmental consulting firm. She was said to have experience in health risk assessment with some background in toxicology.

The cross-examination became stuck at one issue: the "slope factor" of carcinogens, which regulatory agencies use in their health risk assessment protocols. It is used to estimate the probability of someone developing cancer after being exposed to a carcinogen. Take, for example, trichloroethylene (TCE), the major toxic chemical found in the groundwater at the site of RCA's former Taoyuan plant. It had previously been classified as 2A, or "probably carcinogenic to humans," by the International Agency for Research on Cancer (IARC). But in 2012, IARC upgraded it to Group 1, or "carcinogenic to humans," citing a large number of scientific reports over the past two decades. The question: Do regulatory agencies change TCE's carcinogenic slope factor once this kind of reclassification happens?

"Would health risk assessments using the older slope factor underestimate the health risk to humans posed by TCE at the RCA plant?" asked Attorney Tsai on the plaintiff's side.

"No," replied Dr. Hurst. "The way IARC classifies carcinogens is not the same as the way risk assessments estimate the additional risk of cancer."

A nasty surprise! We were expecting her to answer "yes" and step into a trap when we prepared this question. Was this going to be a moment when RCA scored during our cross-examination?

"Ask her about USEPA [the US Environmental Protection Agency], not IARC," Yi-Ping texted to the plaintiffs' lawyers. And it worked.

Minutes later, Attorney Lin, the head of the plaintiffs' lawyers, asked to rephrase the question: "Is it true that USEPA reclassified TCE in 2011 as a Group 1 'human carcinogen' and accordingly changed the slope factor of TCE in its health risk assessment protocol?"

Dr. Hurst replied, "I know TCE was reclassified in 2011 and the slope factor of TCE was updated. However, . . ." Well, the rest of the reply doesn't matter anymore. She said yes now. RCA workers were indeed subjected to a higher risk of cancer than studies had previously suggested.[6]

After the session adjourned and everybody came outside the courthouse for our group photo of the day in the gathering dusk, Yi-Ping waved excitedly to Hsin-Hsing. She said, "I've caught a foul ball!"

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EXAMINING AND CROSS-EXAMINING EXPERTS

In the proceedings of the RCA trial, every expert witness is first asked a series of questions in direct examination. This list is submitted to the court by the party who called the witness. Typically, the presiding judge does the asking. Then, attorneys for the opposing party ask their questions in cross-examination. Each phase usually takes two to three days, and they are scheduled one week apart so that both the lawyers and the expert witness have ample time to prepare. Surprise is not a valued feature of the typical civil law court.

Courts in Taiwan generally recess between noon and 2:30 p.m. The lawyers for RCA and their expert witness from the United States usually went to a TGI Fridays restaurant for an American-style lunch. Those for the plaintiffs usually went directly from the courthouse to the NTU College of Public Health. There they spent the two and a half hours discussing what took place during the morning session, conducting urgent searches online, and preparing a strategy for the afternoon session. On many days they would not have time to finish even a simple lunchbox before returning for the afternoon session. During many weeks, the days felt very much like a perpetually extended ballgame. Yet there were memorable moments of straightforward duels and dramatic turning points. August 1, 2013, became one such day.

Professor Pau-Chung Chen [陳保中], testifying on the side of the workers, was grilled the entire morning on the issue of the "healthy worker effect."[7] The defense lawyers asked him to give documentary evidence explaining why the healthy worker effect should be expected to produce a 20% markup in observed incidence or mortality rates. During the two-and-a-half-hour lunch period, Professor Chen carefully read over the scientific journal articles provided by the defense lawyers as appendixes to their question. He found in them the answer. Toward the end of the afternoon session, Professor Chen stated to the court that, on page 1 of the defense's appendix 6, it clearly says, "Background occupational studies typically observe a 20% [underestimation due to healthy worker effect]." After a lengthy negotiation, this statement made it into the court record of the day. In addition to affirming the "healthy worker effect," it demonstrated to the court that counsel for RCA had paid little attention to the documents they had submitted to the court.[8]

In addition, on the morning of August 8, the defense attorneys submitted a one-page document to the court. They then demanded that Professor Chen translate it from English to Chinese on the spot, sentence by sentence, and confirm the translation to the court. The document reported that, in the polluted groundwater at the site of US Marine Camp Lejeune in South Carolina, there was "limited evidence" showing incidences of various cancers related to the presence of TCE, tetrachloroethylene, benzyne, and vinyl chloride. The professor dutifully did what the defense asked. However, by that afternoon we had printed out the entire report, more than three hundred pages, and submitted it to the court. Professor Chen then called the

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court's attention to the fact that this study had been done by the US National Academy of Science with funding from the US Department of the Navy—the accused party in the Camp Lejeune controversy. He then explained that the Centers for Disease Control in the US Department of Health and Human Services had already published an open letter protesting the bias in this study.

Cross-examination of an expert witness called by the defense was far more challenging to the advisory group than direct examination of witnesses called by the plaintiffs. We have much more time to prepare for the latter with help from our experts. In cross-examination, however, the plaintiffs' lawyers have to quickly and correctly grasp what was presented in direct examination and then respond promptly. Expert witnesses called by RCA from across the Pacific Ocean stay in Taiwan for only two weeks. More days means more expenses paid by the company. Cross-examination has to be ready in one week following the direct examination. Not only do we have to have the list of questions ready and submitted to the court before the sessions; we also have to compile the stack of appendixes. And if the appended scientific articles are in English, we have to translate them into Chinese before submitting them. Many memorable sleepless nights for the RCA case have been spent preparing for the cross-examination of expert witnesses, with plaintiffs' lawyers, assistants, scientists, STSers, and student volunteers all working together.

These efforts paid off. With painstaking preparation on the side of the plaintiffs' lawyers in cross-examination, the first expert witness RCA called at the district court trial, a Taiwanese American radiation oncologist at a UCLA hospital, turned out to be a fiasco for them. So much so that district court verdict states in unusually harsh tone that

> the court can therefore understand that Dr. Steve Lee [李百勛] was deliberately trying to mislead the court by double talk, word games, and using the so-called hypothetical statement in his comment. All through his testimony, he was fully aware that [the plaintiffs' arguments] are based on IARC monographs, that trichloroethylene (TCE) has been classified by IARC as a Group 1 carcinogen and tetrachloroethylene (PCE) has been classified as a Group 2A carcinogen, and that both chemicals may cause cancer in the human body. The content of the expert report submitted by Dr. Steve Lee is thus not qualified to be considered by the court.[9]

We may never know how much the anger at a purported scientific expert witness trying to mislead them weighed in the deliberation of the three-judge panel at the district court, which eventually ruled in favor of the workers. We do know that the workers' lawyers and advisors like us learned to treat every bit of expert testimony and every court session seriously. To the extent it sometimes feels like a ballgame, it is a ballgame we play with passion.

As exciting as these quick back-and-forth responses were in the midst of the slow-motion movements of the court proceedings, what was most exhilarating for Yi-Ping was to see the issue of science and gender surface and be discussed formally in court.

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On August 1, 2014, the prominent public health scientist and leading advocate for victims of RCA's toxic exposures, Professor Jung-Der Wang [王榮德], testified on behalf of the workers. By the end of the morning session he had been questioned repeatedly by the defense lawyers about cancers from TCE exposure. The IARC reporting had indicated that the most likely cancers resulting from TCE exposure are kidney and liver cancer. Yet research on the Taiwan RCA workers had found a large number of breast and cervical cancers. How could one possibly say, then, that cancers among RCA workers are caused by TCE?

Professor Wang tried to answer by reiterating again and again that exposure to organic solvents such as TCE can cause a whole series of different cancers. He emphasized the factor of "competitive cause of death." In other words, someone who dies of kidney or liver cancer could not die later of breast cancer. But the point did not seem to work very well to deflect the RCA lawyers' questioning.

During the lunch break at the NTU College of Public Health, Yi-Ping reminded Professor Wang that international studies on occupational exposure of TCE are mainly done on populations of male workers, tracking their long-term health outcomes. Naturally, these studies would not find breast and cervical cancers. That afternoon, Wang led the defense lawyers through IARC's list of occupational epidemiological studies on TCE, looking for the variable of sex. They were forced to acknowledge that the studied subjects have indeed been predominantly male. The lack of systematic study of women workers clearly explained why the predominantly women workers at RCA could not find published scientific evidence connecting their illnesses to the chemical exposure they had collectively experienced.

The Taiwan STS community has long made gender and science and technology a central concern. Her interest in and concern for the health of women workers is also what led Yi-Ping to initiate research on RCA in the first place. She has long been a vocal critic of the gender blindness of epidemiology, toxicology, and health risk assessment. Although the gender issue rarely came out explicitly during the trial as a compelling source of evidence, on that afternoon in the courtroom and with a simple nudge, the RCA lawsuit had entered the inner workings of science and started talking about gender.

KEEP ON AND SPREAD OUT

The high court verdict on the RCA case asserts that the company had been using at least thirty-one toxic chemicals. These chemicals are deemed likely causes of sixty-five types of cancers by such authoritative scientific and regulatory bodies as IARC, USEPA, and US Centers for Disease Control and Prevention, drawing on both epidemiological and toxicological modes of evidence. All plaintiffs who are diagnosed with or have died of any of these sixty-five cancers are eligible for compensation from

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RCA and its parent companies. Recognizing the multiplicity of causation became significant progress in itself. In most real-life situations, victims of toxic exposures throughout the industrial world are exposed to mixtures of hazardous chemicals. The so-called one-molecule-one-disease model had often worked against victims when they tried to seek redress for their suffering.

The Supreme Court verdict of August 2018 upholds most of the high court decisions on the difficult legal questions of causation, burden of proof, and statute of limitations. It also pierced the corporate veil by holding foreign parent companies jointly and severally liable for wrongdoing as their local subsidiary. This means that a total amount of approximately 564 million Taiwan dollars (US$18.3 million) in compensation to 262 dead and seriously ill victims is set and final. However, the Supreme Court verdict also questions the high court's reasoning for awarding damages to 246 plaintiffs who have not yet been diagnosed with serious illnesses. The high court's 2017 ruling stipulated that, even without outward expressions of harm, "subcellular-level damage" has occurred when a person is exposed to known carcinogens. The Supreme Court remanded cases of some 200 such plaintiffs back to the high court for a retrial.

The RCA case has set many records in the legal history of Taiwan. It has the largest number of plaintiffs, largest amount of damages awarded (although still meager compared with the norm in other industrialized countries), most complex scientific evidence, and greatest number of expert witnesses and length of scientific expert testimonies at court. This accomplishment of STSers in Taiwan was achieved in close and extended collaboration with the organized victims, social-movement activists, lawyers, scientists, and many student volunteers. These experiences have become integral to the formation of the STS community in Taiwan. The case has successfully demonstrated that occupational diseases, such as those at issue in the RCA case, raise questions and concerns similar to those in environmental pollution and food safety, even though the latter often receive much greater public attention (H.-H. Chen 2016). The important collaborations in the case have started to bring about much needed changes in civil court procedures, the labor and environmental movements, and we hope, science as usual as it lives in the realm of public health.

ACKNOWLEDGMENTS

We would like to thank all of the victims, activists, lawyers, and volunteers of all kinds, including scientific expert witnesses, for their perseverance over the years in the RCA campaign and lawsuit. We also are grateful for the warm, collegial support of the Taiwan STS Association and the research funding provided by the Ministry of Science and Technology of Taiwan. Our collective endeavor would not have gone this far without those combined efforts.

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NOTES

1. The translation of journalistic work on technological disasters such as Chernobyl and Bhopal played crucial roles in shaping such a sensibility in Taiwan in the 1980s when it was still under stringent censorship. The translation of Ives (1985) is one prominent example. Two translators of that anthology later became leading figures in the Taiwan STS community.

2. See Wang (2008) for a brief introduction to the judicial reform movement in Taiwan since the late 1980s.

3. See Tsai (2019) for a summary of the district court verdict for this second group of plaintiffs.

4. A short answer to this is that in 1912, when the legal system of the Republic of China, which Taiwan has inherited now, was established, most Chinese didn't speak the official language, Mandarin Chinese. Having puzzling remnants is probably common among countries with a colonial or imperial past.

5. The French phrase "*intime conviction*" is often used to describe the central criteria of the evidentiary law in the civil law (Continental law) tradition, which the legal system of Taiwan has largely inherited. It refers to the state of mind of the judge who believes that the facts used to determine the verdict are actually true. See, e.g., Engel (2008).

6. Court record of the Taiwan High Court for the session starting at 2:00 p.m. on March 31, 2017, in the civil tort lawsuit 104 Zhong-Shang No. 505, 5–6 (臺灣高等法院104重上505號侵權行為訴訟，106年3月31日下午2時言詞辯論庭筆錄，第5–6頁).

7. Many epidemiological studies of occupational diseases take into consideration the "healthy worker effect." Workers usually exhibit lower overall rates of death and serious diseases than the general population because the severely ill and chronically disabled are ordinarily excluded from employment. The incidence ratio of a certain disease observed among a group of workers should therefore be given more weight when compared with the same rate among the general population. In his testimony, Professor Chen stated that contemporary studies of occupational health often use a 20% markup to take into account the "healthy worker effect."

8. Court record of Taipei District Court for the session starting 2:40 p.m., August 1, 2013, for 95 Zhong-Su-Geng-Yi No. 4 Civil Tort Lawsuit, p. 16 (台北地方法院95重訴更一第4號民事侵權訴訟，102年8月1日下午2：40準備程序庭筆錄，第16頁).

9. Taipei District Court 95 Zhong-Su-Geng-Yi No. 4 Civil Verdict, p. 107 (台北地方法院95重訴更一第4號民事判決，107頁).

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2

THE GROUND KEEPS OPENING UP

Building an Infrastructure for Data Appropriation

Dawn Nafus

THE FIRST MEETING

Finally, we were really getting started. After much research and concept development, we were finally in the nuts and bolts of prototyping Data Sense. The prototype was a web-based data exploration software for people who use data to keep track of a health or personal problem—self-trackers. Self-trackers do not necessarily have the same skills as a data scientist but often ask questions about what data could mean beyond the meanings that are already supplied by tracking devices. Normally my job consists of research to identify where new technology or business opportunities lie, and this was the first time I would be involved in a hands-on way. I wanted to start working hands on because helping people work with data on their own terms mattered to me. Asking questions requires interpretive work beyond consumption. The interpretive work is not just statistical; it involves critical reflection about the circumstances in which the data was collected. Because this was both intellectually interesting to me and, in my view, socially beneficial, I cared deeply about whether it was possible to support self-trackers in this process, and I was lucky enough to be working with collaborators who similarly saw the value of doing so with software.

I work in a research arm of a large company, Intel, where the connection between research and product development is never straightforward. Markets for technology coalesce in complex ways that are never visible at the outset, which creates an unsteadiness that can be disorienting and alienating, not at all like the formerly celebrated and now panned out-of-the-box, disruptive thinking Silicon Valley became known for. If we were crazy to pursue this, it was a thoroughly researched, highly experienced form of crazy. In their work as engineers, or in their personal lives, my colleagues on the team knew the value of data exploration as the first step to meaning making. They also knew that context was the key to establishing data's meaning,

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so it made sense to them that my ethnographic research had shown that self-trackers were good at contextualizing their data and did not always take the messages from tracking devices at face value. In fact, one self-tracker in our early research was so careful with his data, both mathematically and conceptually, that one of the computer scientists on the team exclaimed, "This guy's my hero!" Indeed, others on the development team were themselves self-trackers. These confirmations from multiple perspectives softened my anticipation of being told I was crazy yet again, which had come to take on a more stinging valence over the years, being both a woman and a nonengineer in a male-dominated tech company.

In these circumstances, I felt a deep sense of responsibility to get it right. This first daylong team meeting turned to discussion of the types of data that would be ingested into the system—strings of text? Numbers? URLs? Enum (or answers to multiple-choice questions)? Something called a float? I didn't understand why we needed to anticipate all these things beforehand, but I took it on trust that we did and secretly wondered to myself what it could possibly mean for a number to float. It became important to know whether time series data would be the only kind of data that we would need to bring into this system. "Dawn, do self-trackers collect any data that isn't time series?" I had no idea. I could tell them all about the politics of governmentality and measurement, but whether only time series data was in play, I had no idea. I could guess that time series was probably the most common data type—keeping track involved a notion of time, after all—but whether other data types were of note was a mystery. This prompted a debate about what we meant by data "types"—enum and float or heart rate and blood pressure?—and how much definition we needed at this early stage.

At some point, our newly hired full-stack[1] developer said that we didn't have to solve all the corner cases just yet. I had to ask about this one. If I didn't understand the design and development process from the beginning, there was no way I'd be of much use. "What's a corner case?" I asked. Quizzical looks turned my way. It turns out that defining a corner case was something I was expected to be able to contribute to. It is a scenario of use that is rare but could be necessary to take into account when designing a system. Surely it was my job to define what those are, so exposing myself as not even having the language for it would have earned me the label of "crazy" in a less forgiving team. Later I would come to understand this forgiveness not only as a sign that I was finally working in an inclusive team but also as a sign that we were not building a data visualization tool, but rather an infrastructure where the unknowns would proliferate and put everyone on equally unsteady footing. Exploratory data analysis required us to contemplate design considerations that ranged from database issues (in tech industry speak, low in the stack[2]) all the way through to considerations that involved no technology at all, up so high it was above the stack entirely. Exploratory data analysis complicates any naive understanding of what serves as infrastructure. It is a sociotechnical process

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that makes it impossible to assume which elements constitute the visible figure and which the invisible ground.

This chapter describes what is involved technically and socially to support that kind of analysis and how my own assumptions about data and infrastructure unraveled for me. Data is regularly appropriated or contested by supposed nonexpert groups like self-trackers and air quality activists. Yet supporting alternative interpretations of computationally dense data sets requires more than alternative social and cultural frameworks. It also requires alternative technical infrastructures to support the formulation of new stories that are told with data. Our infrastructure exposed yawning gaps between computational systems and social worlds, which manifested as uncertainties or unknowns in the design process, despite decades of datafication (Van Dijck 2014). Our design ethos was to help people *find* the story in data rather than telling the story to them or for them. This ethos opened up a whole world of unknowns, both technical and social, precisely because the work of finding the story in data is unpredictable. The unfolding of unknowns exposed a double invisibility: it made the invisibility of infrastructure become visible, which in turn exposed the equally invisible nature of exploratory data analysis work, which is not about making bold claims and storytelling but about doing the relatively unglorious work of merging data sets, shipping them between systems, and finding roads in the data that don't reveal much meaning. By building a data infrastructure, we found that in contexts in which data work lacks a social location—a defined occasion for data wrangling and merging to happen—the appropriation of data is deeply constrained. We also found that the unfolding of unknowns can be experienced viscerally, sometimes in the form of excitement but often in the form of worry.

To tell this story, I trace the project in rough chronological order, from the earliest research through development, testing, and its somewhat ambiguous endpoint, showing what opened up at each step along the way.

THE WORK OF SELF-TRACKING DATA

Data Sense started life in a research program known as Biosensors in Everyday Life.[3] This was a three-year, four-university interdisciplinary research program organized and sponsored by Intel, where I served as the program manager. It was a program that set out to better comprehend the social dynamics that product planners would encounter should they choose to invest in consumer-grade biosensors, which are a type of sensing technology for detecting substances in the body or in the environment. It is useful to know whether the social dynamics would support or inhibit markets for such devices and what the likely usage scenarios were. In *Quantified: Biosensing Technologies in Everyday Life* (Nafus 2016), the investigators from that program and I described in depth the sociological and anthropological questions addressed in that research. What might it mean for medical knowledge and institutions to have

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consumers appropriating medical technologies? What are the consequences of an expanded role for data in daily living? How should we think about notions of public and private when multiple people are implicated in the same data set and when a data set is nominally about an individual but in reality about so much more? What are people actually doing with biosensors and their predecessors?

These were large, complex problems in their own right, and it was my job to "distill" all of this research for those who were making business decisions with it (an example of the distillation can be found in figure 2.1). The quotation marks indicate that my translations were hardly a distillation of the essence of the research; they were an opinion about what was important. My academic colleagues on that program indulged me in an exercise in which, for each social dynamic they identified, we made some structured speculation about how liable to change each was. For example, if there was a widening gray area between medical knowledge and lay knowledge, would this expand or contract in the coming years? What could the consequences be? Through this structured speculation, the answer I ended up giving to the business about whether a market was feasible was short and blunt: there were lots of enabling dynamics and some inhibiting ones, but the inhibitors would not render the market unviable. I said that privacy was going to be incredibly difficult to get right and would require real investment to do so.

The research program informed a number of business decisions beyond Data Sense, but here I focus on how we arrived at understanding there was a need for software of this kind. It started in the strand of the research focused on data literacy. At

Questions Intel asked in 2010	What we learned
• Is the health care industry going to adopt consumer biosensors as an extension of care?	• Not easily or quickly. Consumer data makes work and liability for doctors. Data that matters to consumers is not what matters to doctors.
• What usages make sense?	• Consumer-driven biosensor data is extremely helpful when just getting a pill doesn't work (allergies, asthuma, fatigure, migraines, etc.).
	• Domains with a lot of cultural baggage (weight management, genetics, etc.) find it harder to deliver real value, because the necessary action is out of the user's control.
• Which sensors have the greatest potential?	• Patterns and triggers are heterogeneous. Next-generation capabilities matter, but no one sensor is the "killer app."
	• Combining environmental sensing and personal sensing currently is ripe for innovation.
• How do we present scientific data in a simple way?	• People can (and do) make sense of complex datasets when it matters to them. Sheer complexity isn't the problem, putting it in context is.

intel | 1

2.1 A transformation of scholarship into technology company frames. This slide was used at the final meeting between Intel stakeholders and Biosensing in Everyday Life research program investigators.

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the time, my strategic planning colleagues had a concern about whether health data could be made simple enough for nonspecialists to interpret in an appropriate way. There was, of course, a heavy dose of medical paternalism in the framing of the question. The fears in the medical community about people becoming unduly frightened about scary-looking data are wildly out of proportion to the rate at which this actually happens (Brown 2016). This medical aspect was compounded by long-standing tropes within the technology industry regarding the ill-informed computer user, who is the imagined source of error in otherwise well-designed programs (Woolgar 1990). "Prosumers," or lead users, who do technical work in the act of consumption are acknowledged, but fantasies of machinic control—that the device would nudge the consumer to act in certain ways—loom large. As wearables emerged as a product category and intersected with medical notions of compliance, the figure of the prosumer had become eclipsed by a quasi-helpless consumer figure who required guidance via automatic notification to stop or start a certain behavior (Dow-Schüll 2016). The work she needed to do was to discipline herself in response to the numbers that devices delivered, such as taking ten thousand steps. She was not expected or trusted to do the intellectual work of interpreting numbers. To her, they were supposed to be both self-evident and self-efficacious.

However, this strand of research showed that there was substantial room for alternatives. We found that there was no such thing as simple or complicated data parsings or calculations; what mattered was what people were attuned to. This work built on Lave (1988) and Verran (2001), who point out that the concept of multiplication is not inherently more complex than the concept of length and that the ability to get it has to do with whether the mathematical procedure is in tune with ready-to-hand cultural and linguistic structures. For example, Euro-Americans know what a percentile is not because we know it mathematically but because most of us have been measured in those terms. Building on these ideas, investigators from Goldsmiths College (Day, Lury, and Wakeford 2014) showed that this cultural process of attunement continues in the context of big data systems. In encounters with social media metrics, for example, lay people show a tremendous facility with the sorts of calculations made possible only by large-scale, complex data sets (Gerlitz and Lury 2014). Similarly, a team from Lancaster University discovered the extraordinary lengths some people would go to in order to do data mining on their own direct-to-consumer genomics test results (Kragh-Furbo et al. 2016).

My own parallel research on self-trackers in the Quantified Self community (Nafus and Sherman 2014) showed that the willingness to spend time with data and to derive meaning from it was not necessarily a function of having STEM (science, technology, engineering, and mathematics) skills but more a function of being in a situation that required good data, such as health conditions like insomnia or migraines that could have an avoidable trigger in everyday living. People with these conditions are often willing to spend time trying to understand patterns because they could

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very well discover ways to prevent their symptoms. In some ways, they also stand a better chance of success than a professional statistician or clinician if the issue is better characterized with data from outside the clinic than inside it. Through this research program, the researchers and I shifted the problem space away from questions of how to make data simple enough to defy any reinterpretation and toward questions of how to design for appropriation. That is, how could we support users' interpretation of sensor data as a function of context?

At this point we had an intuition that current tools were not doing this job well. For example, one self-tracker in my research had combined a daily step count with autoimmune symptoms data and learned that, over the long term, taking too much exercise was triggering her autoimmune disease (Wheelwright 2016). She made this discovery in part because she happened to use a fitness tracker that offered aggregations of steps by months, not just days. Most steps counters offer daily step counts because daily management of exercise is the manufacturer's intended use, but daily aggregation would have made this long-term pattern visually imperceptible. If her problem had been related to a seasonal recurrence, a different graph again might have been needed. If she had three years' worth of steps data, to create such a graph would require advanced knowledge of the right functions in Excel, if indeed the data can be put into Excel at all. If it had been recorded once a minute, most spreadsheet programs would stop working because the file size starts to get too big after three years.

Seeing the pattern clearly also requires the ability to annotate the graph with a timeline of symptoms, which is a capacity largely unavailable on sensing devices or visualization tools. And what about spatial patterns or patterns related to another source of data, like weather or air quality? The latter would require knowing how to deal with time stamp formatting and time zone alignment, which is a problem that people don't usually encounter unless they are developing software. The goal in this context, though, is not to develop software but to get to the point where it is possible to identify spatial or temporal recurrences. In this case, Jacqueline Wheelwright was able to pull together the right data skills and interpretive skills to find meaning in her data that was useful to her, but there are many other circumstances in which she very well might have hit a wall and not found meaning.

If we take a step back, then, and consider the figures for whom the relevant tools have been designed, we can see a split between tools for general-purpose data wrangling, in which the point is to maximize the available ways to parse data, and tools for nontechnical people—consumers, not prosumers—that minimize the possible parsings available and communicate only the designer's intended meaning. Clearly, this divide stems from market assumptions about who does what kind of data work. That split, however, does not hold up to ethnographic reality: there are indeed people who are not engineers or data workers but who are prepared to do some exploratory data work. Such people make for an ill-defined cultural figure, however. Only nascent cultural and social formations support them, like the Quantified Self community,

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community-based participatory health and environment research, and now, the MyData movement (see Lehtiniemi and Ruckenstein 2018). Data exploration is largely invisible work that a person does, not who a person is. This is true for both people who do not identify as geeky and for people in professional data science circles, where exploration and cleaning is widely acknowledged to be 90% of data work, yet this is rarely taught explicitly (Dumit 2018). Data exploration does not contribute to identity formation in the way that learning to code and learning data science feature in the cultural imagination.

This third figure, neither coder nor consumer, can come from either those who see a problem and cobble together tools or ramp up on the data skills needed to understand it or those who already have data skills and learn to do a deeper, more critical reflection of the data's context (for a description of those skills, see Loukissas 2019). In practice, the third figure comes more often from the latter group than the former. This is in part because of a lack of cultural location for this third figure—getting to the point of needing data can be a sign of the direness of one's situation, not identities or ambitions. It also stems from the high level of investment required to deal with conceptually irrelevant matters like time stamp alignment. Even professional data wranglers spend an enormous amount of time dealing with such issues, and what constitutes a lot of time for a professional will stop the works entirely for someone else. Therefore, the Data Sense team saw value in automating what could be automated and accommodating file sizes that break spreadsheet programs. The alternative is either working at a command prompt, which requires an interest in programming per se that few self-trackers have, or working with a data visualization program, which contains useful visual tools but few computational tools like aggregation functions or time series correlations.

The gap between professional data wranglers and self-trackers can also be seen in the practice of churning through visualizations before finding the one that speaks to something meaningful. Self-trackers with data skills told us pointed stories about converting data that recorded the days when a certain activity happened to the days when it was skipped. A person needs to have faith that the conversion would show something at all in order to go through all the pain to render it visually! Such faith is not well founded, though. Usually, finding meaning in data means tacking back and forth between the parsing and the visualization, ending in multiple parsings and visualizations that prove meaningless. It means toggling between days of an activity and the days skipped or churning through different data sets brought in and out of the same graph. This tacking back and forth between computation and graph, recalculation and new graph, and then back to the old graph for comparison is central to exploratory data analysis, whether doing self-tracking or in the lead up to writing an algorithm. However, what was clunky, slow work for computer scientists was impossible for others. In fact, one data visualization professional recommended to me, as someone learning data skills, that the best way to find the right visualization is to

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start by sketching and avoid the pain of doing it computationally until I was more confident of the right direction.

These constraints in the work process showed us that very specific technical support was required before this third figure stood a chance of reframing the meaning of data. Reducing the programming work required for data exploration was a problem that we could make headway on as an engineering lab. It would be an experiment, but what kind of experiment? It was a commercial experiment in the sense of having a long-term commercial goal of enabling user-driven innovation in a market that clearly needed it; our company stood to benefit from overall growth as the supplier of server-side and client-side hardware. This commercial motivation meant that we focused on digital data rather than analog data appropriation (which has its own enormous advantages—see Guggenheim, Kräftner, and Kröll 2018). However, it was not a commercial experiment in the sense that there was no attached business model or marketing that was also undergoing testing.

It was also not entirely a social experiment in the inventive methods sense, in that it was not designed to optimize for social research gains (see Marres, Guggenheim, and Wilkie 2018). Still, it was related to that approach in that we were radically open to all sorts of possible social outcomes, and we were learning something new about data cultures. Our positionality informed our choice to focus on those who believed they needed data but did not have proper access to it (Kennedy and Moss 2015), as opposed to those who had too much data and did not need it but nevertheless suffered the repercussions of others possessing data about them (Van Dijck 2014). Beyond that choice about audience, we were not committed to any preconceptions of what self-trackers would do with such a system, if anything, although obviously, one cannot build a tool without hoping someone will use it in some capacity. Which capacity, however, was not something we were attached to.

It was a quasi-experiment in the engineering sense, too. To explore what it takes to facilitate data appropriation, a working system was necessary. It need not be full production quality, but it did need to go well beyond a nonfunctional demonstration, or a set of tests of specific components, or a "hacky" effort to pull together off-the-shelf features.[4] It was a matter of engineering research to identify the technical approaches necessary to handle data of these types and sizes, just as much as it was a matter of social scientific research to explore how people might encounter data in circumstances in which some programming tasks were automated. Thus, it was not a product development exercise, but it still required building an operational, full-stack system that looked almost like a minimum viable product.[5]

FIGURE AND GROUND

Exploratory data analysis, in which the analyst tacks back and forth between visualization and calculation, forced us elaborate the connections between figure and

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ground. In working on Data Sense, I found myself relearning in an embodied way the invisible nature of infrastructure as described by Star (1999). Infrastructure became very visible to us, not because it broke down, but because it had to be built up in the first place. We knew that in order to render data visualizations at all, we would have to offer some means of account log-in, data ingestion, and storage and management. That is, users needed to have a way of knowing what data exists in their account and to have a means of pulling it in and out of the system and in and out of a visualization within the system. These things were the ground to our figure of exploratory visualizations, which in turn had to be malleable enough, and traceable enough, to serve as ground for the larger process of making meaning. We contracted with a local design firm in order to wireframe (a middle stage between concept design and full-fledged design specification) the initial version of the website. That work supposedly included both ground and intermediary figure of visualization. We quickly discovered that we were barely able to get through the "ground" part in the time we had allowed for both.

The more areas of the ground we defined, the more they demanded specificity, which opened up yet more ground. Even a wireframe design could not proceed without knowing how many data streams (such as heart rate and steps) a typical sensing device offers. If we wanted to facilitate importing data from a service that had five data streams, we might need to design a simple drop-down menu, but at twenty data streams a different interaction would be necessary (see figures 2.2 and 2.3). This forced us to confront the issue that people might think of their data only in terms of the source, like "my Fitbit data," and not as a set of individual measurements, and so we needed to devise ways to preserve the ability to identify the source alongside the individual referent. Would users want to create derivative data sets, and if they did, were the data sets interstitial and throwaway, or a final product to be stored separately? Would people care about the ability to constantly update their work with live data feeds, or did they see their data as already collected? Would updating be affected by the presence of derivative data sets, which are created at one moment during analysis? In building databases, back-end software systems, and front-end interfaces, we need to make an assumption about these things, yet we had none because the tool had not yet been built.

Questions of how many sources people would have, how they would organize them, and how often they would need to rename the sources or the streams needed specification before we could make appropriate interface and database design decisions. These were interstitial features of the ground of exploratory data analysis, but they kept pushing into the figure. These types of questions were really infrastructural questions, and that is the reason I found myself in a discussion about data types, and not visualization, in the team's first meeting. The infrastructure became visible upon building it and an area of focus that necessarily situated the user as background. That is, we needed to know what manipulations were implied when a self-tracker says she

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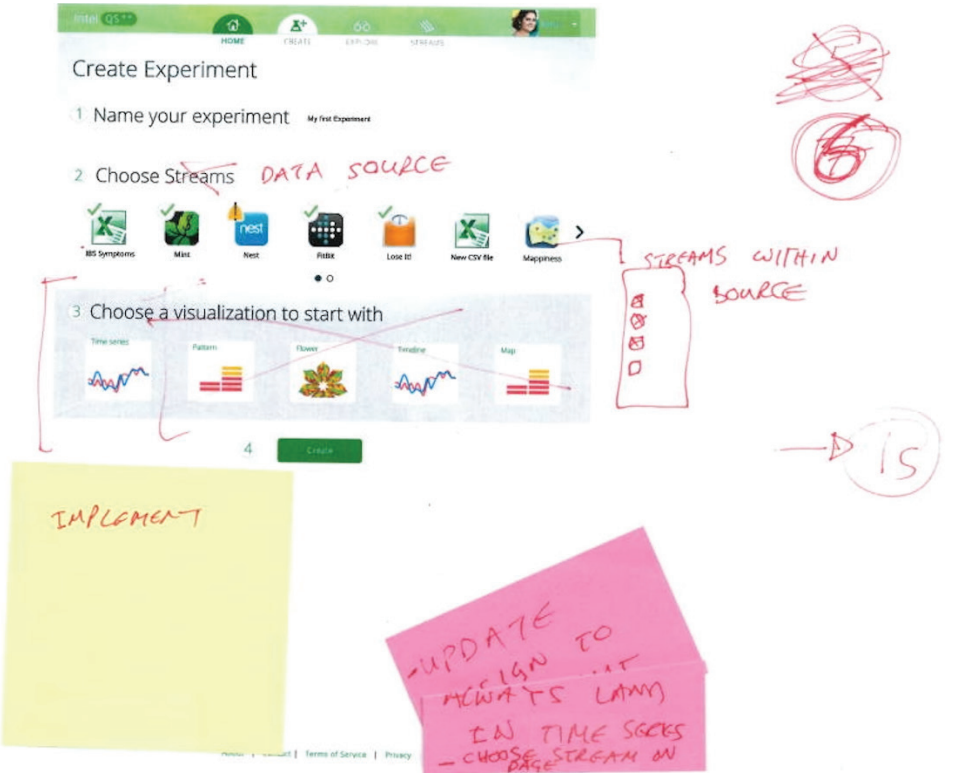
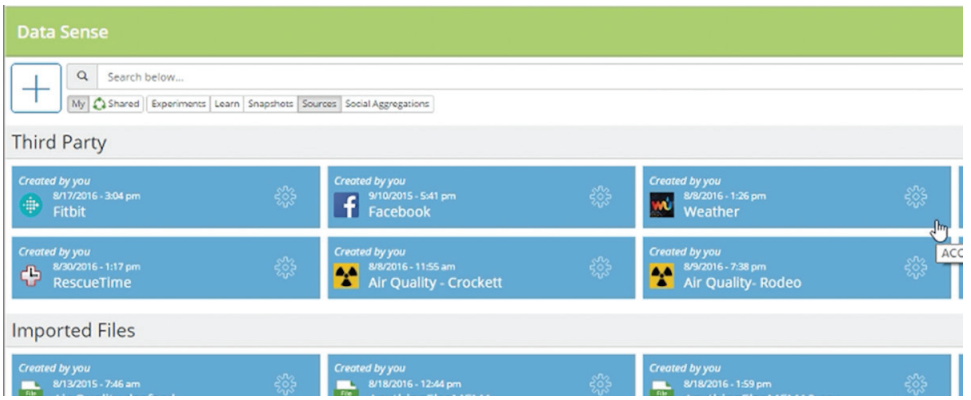


2.2 Hand-drawn markup of our initial concept design when we realized that structuring data access was more complex than initially thought. These changes suggest a different way of handling data to reflect the difference between a data source, like "my Fitbit data," and a data stream, like "heart rate."



2.3 Final design of the live system. The feed-like structure accommodates any number of items of any type. We changed to a feed structure after having discovered that users have significantly more data than originally anticipated. Unlike drop-down lists, feeds accommodate an infinite number of items.

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tracks the days she skipped something (or whatever she did). How they coalesced into a story was hard to keep in sight with so many underlying questions pressing.

As in a cascade, defining how data moved in and out of the system only opened up yet more ground. The question "How much data do people have?" proliferated into ever more specific aspects and technical requirements. System testing showed just how much the sheer number of megabytes affects the ways of bringing data into the system. Smaller files (i.e., data sources) could load within the time it takes for the browser to time out; larger ones needed background processing. Similarly, when trying to render the data on a screen, how many bits each individual data stream contained affected what we could render. If a data set has a million points, trying to represent them all would lead to the browser timing out before any line was shown at all. The original algorithm we used to render a line graph picked points at regular intervals (say, every fifth or twentieth data point, depending on the size of the data set). This led to spikes or dips being left invisible and users believing their data had gone missing. In fact, it is so easy to think of an algorithm as something that makes a classification, and a line graph as something that contains raw data, that when the error first happened to me I felt a visceral unease in my stomach, so disorienting was it to see my raw data—my grounds to an analysis—being reduced in a way that was not faithful to the spikes and dips that I had come to believe characterized the data. No amount of believing the STS exhortation about raw data being an oxymoron (Bowker 2005) can remove that bodily disorientation. As with other infrastructures, none of these things matter to the intended use of data storytelling per se, but became crucial bottlenecks when we got it wrong.

Once the grounds of data ingestion and management were mostly settled, we found ourselves elaborating an entirely new category of ground around the visualizations. We knew that self-trackers did not go directly from raw data to the exact visualization that they could make meaning from. We also knew that self-trackers tended to have on hand more data than is reasonable to look at in the same visual field. A Fitbit alone yields twenty-seven separate data streams. For these two reasons, we needed to support interstitial activity that would allow people to go back and forth between heterogeneous data streams. We arrived at the notion of an experiment in which users could hold steady a small handful of data to visualize in multiple ways, without having to load data and then render it for each new visualization. One account could have many experiments loaded with different configurations of data, and the state of each experiment would be saved automatically, much as Google's online office tools do. This provided a scaffolding to keep many iterations going in parallel, which we thought might better reflect how people do exploratory data work.

However, other tools had no equivalent of our experiment feature, so we had no idea how many experiments users would want in their account. Two? Five? A deep list of them? We initially underestimated the number of data sources and streams

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people would have (whether it was Fitbit data plus a file, or twenty files with ten parameters each, or something else) and the number of experiments they would want to keep running at the same time. This led to a costly and lengthy redesign of the ground, right in the middle of the project. Although this was hugely frustrating for everyone involved, our initial wrong guesses said something about the invisibility of exploration work. It showed palpably, and indeed painfully, that there are more data points and iterations in exploratory data analysis than one might assume, even if you have observed self-trackers' practices closely, and even if you have done exploratory data analysis as a professional. It exposed a forgetting of sorts built in to data exploration practices. All the visualizations that didn't work, and those other data sets that didn't turn out to matter, fade away from memory. The forgetting made it difficult to estimate the number of roads traveled in infrastructure building.

That experienced software developers, designers, and engineers shared my hope that we could get to the "figure" part (the visualizations) relatively quickly speaks to an even deeper sense in which infrastructure is inherently invisible. I was the only one new to the design and development process, yet we all shared the hope that we could begin designing the "visualization" part in the same round of work as the "infrastructure" part. I developed the suspicion that perhaps all this talk of agile development methods and iteration was really a way for developers to deal with the inherent invisibility of infrastructure. Although it is easy to deride the tech company ethos of agile methods, and its more nefarious twin of "move fast and break things," I came to understand that once we cast ideologies of speed aside, there is an underlying recognition in these metaphors that one cannot know what one does not know without having done it yet. The only way to learn is by attempting to concretely define in detail a working system and expose more unknowns. It is no fun to see a chasm open up of yet more ground to be developed, which in turn requires yet more budget negotiations to get the development done, and I did indeed find a coping mechanism necessary. The notion that this was a known problem, an agile process, seemed to help. A better description of "agile" might be "move slow and learn things" because new grounds kept opening, and yet they still remained grounds. Even fast production seemed slow at the surface. This transformed the notion of invisible infrastructures from a social scientific analytic framework to a sense of vertigo, felt bodily in the anticipation of yet more work that lay ahead.

HOW MANY AND WHAT KINDS OF FIGURES?

Once we did have a working system, or at least a skeleton of a working system, the process of tacking back and forth between visual forms—and forms of calculation—and interpretation, came to the fore. That is, the visualizations that were necessarily treated as "figure" in the building process became "ground" in an interpretive process. We knew, for example, that no single visualization would tell a story in the

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way data visualization gurus like Edward Tufte (1983) evangelize. A visual story is a product of refinement, a claim about the story worth telling, whereas our visualization features were visual tools to *find* the story in the first place. What would make a good visualization in our tool would be forms that get users part of the way there or help them eliminate wrong explanations or dead ends as much as find them. To identify what these visual forms should be, we held a series of Quantified Self community events where a small group shared data with one another, and we participated by making some guesses about ways to process it. It turned out there were some clear patterns to the parsings that participants found to be valuable, such as the time of day when something recurs or the ability to smooth out data that has lots of variability to see an underlying trend. In this way we made reasonable guesses, but ultimately one can only ever guess if the story itself is an emergent property of the interaction between person and system.

If the point is to open ground in which stories stand a chance of emerging, the temptation to add feature upon feature is pressing. This is a normal temptation in product design, but it is complicated here by the acknowledgment that a story could emerge from data in a multiplicity of ways. Heated discussions in our group occasionally ensued about what features were worth adding. Adding control over numerical parsings—the ability to change whether a recurrence by time of day was aggregated by averaging or summing points, for example—was a very different thing from adding visual controls, like control over the color of lines or bars. Our interaction designer unsurprisingly advocated for more visual control because that is where he found meaning. Some of the engineers on the project pointed out that without those numerical controls, the visualizations might not make any sense. Data about steps ought to be summed to get steps per hour or day, but adding up heart beats across an hour or day has no meaning. Indeed, so wildly heterogeneous is our current data culture that our users were not in agreement about which features were easy to use and intuitive and which were hard.

The dimensions of data stories proliferate as different data sets are combined. One datum is unlikely to tell a story, but data in a time series might have a story whereas many data sets across that same time frame might reflect different aspects of the same phenomenon. So the temptation to add one more data type or one more computational or visual control grew stronger the more we tested it with people because they often suggested that the stories they wanted to be able to tell would be possible if only Data Sense could do just that one extra thing. The challenge was ensuring enough of a range that someone could get to a personal discovery of some kind but one not so extensive that cognitive overload sets in because of the need to learn the interaction mechanisms and what those mechanisms do to the underlying data. The computations that the interactions performed are not always trivial to explain. To go back to the earlier example of Wheelwright, the woman who identified her autoimmune triggers in her steps data, she might not have recognized that an aggregation

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function, buried in the advanced-user corners of the interface, was relevant to her, even though changing the aggregation from average steps per day to total steps per month is effectively what she did.

The difficulty of deciding which visual figures would be good grounds for finding a story and of figuring out the best way to show the options to end users without overwhelming them revealed a misalignment of social worlds. In the very act of trying to bring together humanistic, context-sensitive interpretation with contemporary computational capabilities, moments like these made the gaps between those two worlds seem bigger than ever. Fellow data wranglers, and developers working on similar systems for those who *could* code, easily recognized what we accomplished. They saw our work as making a giant step toward easing the work of nonspecialists. Yet those nonspecialists were still seriously challenged, at least some of them. Recognizing both realities is dizzying, almost as crazy making as software makers recognizing both realities was dizzying. Even though we had seen plenty of examples of people who had defied stereotypes of what a nontechnical person can do, we came to understand that our attempt at developing a computational infrastructure around what they had accomplished did not hint at a new market but instead exposed a tremendously complex and subtle set of skills that some self-trackers had built for themselves. There were no simple ways of tidying this problem. There was no avoiding, for example, the need to add controls over the aggregation function (e.g., taking the average vs. summing) that are used to find recurrences by hour of day or day of week. Similarly, if we were going to show correlations, we would need to explain how a correlation coefficient worked and why time series correlations break down in certain circumstances. These were functions we could not make invisible because, in going down different roads to find the story, people would have to encounter them. We could not make the entire world of computation invisible in the way that we can make time stamp alignment somewhat invisible.

As soon as we started to see these limitations crop up in testing the system, we took steps to overcome them by thinking carefully about onboarding. Onboarding involves designing system elements that introduce new users to its mechanisms. For us, this meant introducing users not only to the interface but also to computational concepts. We were careful to not assume prior statistical knowledge, and instead we explained our terms. In fact, the exercise of explicitly naming all the capabilities, tooltip by tooltip, video tutorial by video tutorial, was our way of reinscribing, or otherwise shoring up, this nascent cultural location for data work that was barely emerging. Our onboarding features were radically different from introductory statistics instruction in that they focused on manipulating time series data to find patterns, not probability or statistical significance. This is a different genre of thinking, or dialect, of statistics. It was in part rooted in our sense of data as a "third thing" (Dumit 2018, 271), neither strictly quantitative nor qualitative. Here, numerical data triggered a qualitative analysis of a context because the viewer would know what else

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was going on in her life and why data might spike on a certain day of the week. That viewer does not always need a test of statistical significance to determine whether it mattered. This data dialect is one that few people speak all the time, and, as with a dialect, most are better at hearing and understanding than speaking. It would be perfectly interpretable to present a self-tracking finding in this dialect at a Quantified Self meeting. One could show, for example, a map that marked the average calories consumed in this location versus that. In fact, we built a mapping feature because we had seen some similar visualizations at Quantified Self. However, the conceptual frameworks necessary for a new Data Sense user to *make* that same map were not yet naturalized in the same way that a notion of an average has been naturalized enough to interpret the map. A user would need to know how to import the data, change the aggregation function, and then figure out that location data not only referred to where the user was but also was associated with other data in the account if it overlapped in time. The user would have to know not to expect "my location data" to show up as pins on a map, but that location data would be used as context to spatially analyze other data. A user would also then have to have an intuition that a spatial pattern of calorie consumption could be worth exploring, but if it looked odd on that map, it would be worth cleaning out spurious zeros. Even though we had done a tremendous amount of programming labor to make users not have to think about how to associate location with data or not deal with the zoom functions that aggregate and disaggregate data at various spatial resolutions, making that map is still fundamentally not easy because this is not an analysis most of us have to do on a daily basis. The need to design onboarding features points to a paradox, one in which we were actively participating in the emergence of a cultural location[6] by naming useful parsings of data, yet the need to name them at all reminds us just how emergent this location is and just how little one can assume about what others know.

CREATING A CULTURAL LOCATION, FOR A WHILE

User tests and community-based participatory research served as appropriate and useful cultural locations where the practices of this third figure could emerge. I was responsible for the ongoing user testing for the project, and we tested a range of possible end users, from those with data skills looking for some level of automation to those who saw a need to manipulate data but had no notion of where to begin. For the latter group, I often started an interview by taking the lead and doing a walk-through of the person's data using the tools. Participants absolutely were capable of both bringing their interpretive capacities to bear and learning about new aspects of data they hadn't considered.

For example, I did extensive user testing with a grassroots community group interested in examining the effects of air quality on health. Cardiovascular data like heart rate and blood oxygen from consumer-grade wearables and data from a local

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continuous air quality sensor were compatible enough to correlate. The data set sizes were right for Data Sense because Data Sense could handle amounts of data that spreadsheets cannot but doesn't require commercial-scale big data infrastructures. Our tool and their needs seemed like a good fit, and we worked out a joint experiment in which community members would collect cardiovascular data on themselves, and I would support their analyses of the data using this newly made tool. This in turn enabled me to test whether the tool's features were working and how users interpreted them.

This community was very sophisticated about the dangers of data smoothing because air quality regulations were written with respect to time-based averages. A polluter would be out of compliance if it had emitted benzene above a certain threshold on average for twenty-four hours or for a year. Community members complained that water can be 70 degrees Fahrenheit on average for twenty-four hours, but a burst of boiling water within that time can burn a hand. When I sat down with individual members of the group to explore their personal data, this knowledge did not necessarily automatically transfer. I used a form of smoothing that involved a moving average rather than an average per day. My method was a bit different from the average per day method, but it is something regularly used in reporting financial news so I thought it would not be too exotic. However, doing any smoothing on heart rate data came as a surprise to the community members because smoothing for them was usually a bad thing, a disingenuous thing. Yet there I was, smoothing away so that we could see underlying day-by-day trends of heart rate without having to see the spikes every time they went for a walk. Done on heart rate data instead of pollution data, and done for a different reason, smoothing needed to be introduced again in order to inhabit their imagination of how data parsing worked.

Data Sense was also used in another experimental setting: a group of family caregivers learning to self-track in order to learn something about their own stress. This time in a small group setting, we loaded one volunteer's sleep data into Data Sense and a discussion ensued about his sleep patterns. We discovered using the day-of-week recurring pattern graph that he gets much worse sleep on Wednesday nights, and then he noticed that average duration of sleep seemed low. We toggled back to the sleep data's line graphs and realized they contained a lot of zeros that did not indicate the total absence of sleep but were times he was not wearing the device sensing his sleep. I cleaned out the zeros for him through our feature that enables creating derivative data sets on the fly by selecting points directly on the graph. This participant was not inclined to take the controls and do that cleaning himself, which we had originally designed for. Yet in another sense, this moment was exactly what we designed Data Sense for. He was someone who had no reason to formulate opinions about good data cleaning but saw the need for cleaning because he knew the context of when he was wearing the device. He was able to force the creation of a rendering that was useful in a critical reflection about stress for family caregivers.

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For a moment, these tests created their own situatedness. They were a situation that allowed them to contemplate their data, and seeing their data being transformed by someone sitting in the next chair over made a difference. It made a difference to distribute the knowledge between what data needs cleaning and the gestures needed to clean it. In the course of these encounters, my participants got better at seeing what I saw and came to anticipate the next step. As the interviews progressed, the air quality study participant who was initially stumped by the smoothing process had come to request that I toggle between the smoothed and unsmoothed states and then look at it in relation to the air quality data. In these encounters there was no sense in which people were passive. We were having a dialogue in data and making meaning together. It was a tenuous place, a miniature social arena that allowed these stories to emerge. The software was not well positioned to do that on its own, without a social occasion to look and talk. The onboarding mechanisms were necessary, but the real onboarding was taking place in interpersonal connection, a deeper listening. When supported by a social occasion to look and talk, not just a video or pop-up tooltip, a new kind of imaginary was nurtured between a few people for a while.

In these tests, I kept rediscovering over and over again what the Biosensors research program was trying to tell us all along: that it is dangerous business to make assumptions about what people are capable of understanding. In order to get the development underway, we had to stabilize the figure of the end user who explores data. Yet faced with the reality of the heterogeneity of those people and the unpredictability of the stories each one might tell, it grew nearly impossible to establish a definition or baseline about what was and was not intuitive. There were no levels of beginner or advanced, and that made for a tough design process that required us to assert, rather than assume, an assemblage of computational knowledge and an infrastructure for that knowledge that we thought made a contribution to this nascent cultural location. The wide variability in sociocultural understandings, in conceivable data sets and parsings, and in notions of what makes for intuitive data transformations means that no amount of onboarding or in-tool explanation would stabilize meanings appropriately for everyone. They were unstable grounds on which to stand up an infrastructure project.

CONCLUSION

Building an infrastructure for exploratory data analysis reveals gigantic gaps between computational forms and interpretive forms, necessitating new connections between figure and ground that rarely get named explicitly. When two people sit down together to look at data, it does not always look like storytelling. Data set size and groupings need attending to as much as the meaning behind a moving average and why one would use it. We also saw how little of it can be made invisible through building an

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infrastructure. If derivative data sets are a constant, visualizations need to be transformed, and if data types are unpredictable, choices about these matters cannot be hidden from the data interpreter, even though they do not make for a good story. The underacknowledged, and often undervalued, exploratory work of data was made visible in the act of building Data Sense. The interstitial nature of that work continually exposed yet more areas of software building and testing and yet more areas with gaps between the lifeworlds of computationally dense data sets and our supposedly datafied world, a world that invites us to imagine that data sets could be appropriated but makes it difficult to do in practice.

These yawning gaps in turn raise questions about how data is or is not caught up in social transformation. The real answer to the question of who would use this tool, or one like it, is in the broader social transformations of which the tool is a part. Our goal of elaborating people's capacity to situate data ended in a technical system that could not itself situate data. Perhaps someone who saw society as a thing to be changed by technology would consider that a failure. I do not. It was no coincidence that in the testing, Data Sense did best in group and interpersonal settings like the ones I describe here, where there was interpersonal engagement and socially sanctioned moments to sit down with data, which are remarkably hard to come by even for enthusiastic Quantified Self participants. Indeed, one Quantified Self enthusiast saw immediate value in our tool, by spotting right away that it meant he could now merge the steps data from the various models of fitness monitors he had accumulated over the years and process them as one continuous stream. This is not something that most other users would have spotted at first and indicated he knew something about data work. He noted that finding the time to do that work for his own purposes and not for an employer was extraordinarily difficult, and he knew we had made that work significantly easier for him. No matter how good the tool, the temporal, spatial, and social boundaries that demarcate sanctioned exploration and analysis still matter. Where does time for analysis and reflection fit in the flow of everyday life? Creating a concrete social location for this particular form of thinking is no small matter. Patient support groups, Quantified Self meetups, and community-based participatory research provide glimmers of possibility for such occasions.

One sociotechnical intervention is not a movement. One project cannot change how the cultural logics work and the imaginaries that are ready to hand. A series of interventions, however, is an entirely different matter. The question for this project, and for those who would like data to be used in more socially beneficial ways, is: What alliances are needed for meaningful social transformation to happen? That requires a shared notion of what beneficence looks like, and clearly there is plenty of room for contestation. What at first looks like a beneficial act of valuing the unglorious parts of data work and an act of respect for uncredentialed knowledgeable people could morph over time into increased burdens on more people to do data work (Kragh-Furbo et al. 2016). Indeed, one active area of debate within the air

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quality group I worked with centered on whether fine-grained data was necessary at all when the evidence was so patently clear that air pollution existed in the area and was contributing to poor health and climate change. A lack of knowledge was not the issue, and there was a risk of getting into a scientific "arms race" of sorts in which underfunded community groups were structurally disadvantaged against industry-funded scientists who would make opposing claims with the same data (see Ottinger 2010). The counterview suggested that community groups already were in that arms race whether they wanted to be or not, and it was better to provoke a change in how the data was collected and parsed rather than allowing others to entirely monopolize those discussions. An analogous discussion was taking place in corners of health self-tracking, too.

If we were to take the view that it is better to gain a foothold in conversations that one cannot stop, then our figure and ground design problem comes full circle. The next ground to open up if data is to benefit movements is a social design problem. Intentional thought needs to be put into shaping the social occasions that knit together the data worlds and lifeworlds of those movements. STEM education is not enough to do that knitting, and neither are the research occasions I share here. As Torben Jensen, Andreas Birkbak, Anders Madsen, and Anders Munk show in chapter 5, it is possible to intentionally design a social occasion in a participatory manner without resorting to social engineering. Part of the puzzle of how data figures in social movements lies in figuring out who does the data work in social movements and how and when that work gets done. In a sense, by doing some of the infrastructure-building work, the need for institutional, social, and cultural infrastructure is revealed in a new way. Such is the unpredictable nature of how making & doing projects travel.

Traveling also can reveal one's own limitations. These social and institutional capacities are not capacities that my research and development lab is well positioned to build. As I write this, we are in discussions with nonprofit organizations that could take on Data Sense. These partners have a specific reason to facilitate the appropriation of data and are better positioned to build the social circumstances in which to do it than we are. In this way, it is not far-fetched to see making & doing as a way of participating in larger social movements. Even if the grounds keep opening up, yet again, as they always seem to, living with the vertigo these openings create also makes it conceivable to at least partially shape the world one would prefer to be living in.

ACKNOWLEDGMENTS

I would like to thank Sangita Sharma, Pete Denman, Lenitra Durham, Lama Nachman, and the rest of the Data Sense team. Gwen Ottinger's collaboration, insight, and friendship helped me to understand what the technology was missing. I also

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thank Anders Munk, Michael Guggenheim, Gary Downey, and Teun Zuiderent-Jerak for helpful comments and encouragement throughout the writing process.

NOTES

1. "Full stack" refers to someone who can work across both the "back end" of software systems, which is software components that ordinary users do not see, and the "front end," which is the part of the system that users do see.

2. The "stack" refers to all the hardware and software components necessary to deliver a product or service. The "back end" is considered low in the stack, the front end is high.

3. I am indebted to Suzanne Thomas (pers. comm., November 2017) for pointing out the centrality of work in data systems.

4. The development side of an R&D organization is, to my mind, crucial to enabling making & doing research. Professional developers and computer science students and faculty are not substitutes for one another, even if there are engineering research problems to tackle. Figuring out what kind of coder is necessary for what project is a skill that social scientists would need to develop to do more software-based making & doing research.

5. A minimum viable product is a new product that is sufficiently developed to go into use but not so fully polished that too much investment has gone into it before feedback has been gained from the market.

6. A more theoretical chapter might theorize cultural location in a way that I have chosen not to in order to keep the focus on the specificities of building the software. My point is that, although we could theorize all sociotechnical phenomena as always already emergent, some emergent phenomena are not yet situated comfortably. They neither sit easily in places nor enjoy much recognition. Not all experiences of emergence are quite the same.

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3

A SHIFTING INCUBATION

From Exhibiting Academic Migration to Staging Interactions with Academic Refugees

Michael Guggenheim, Judith Kröll, and Bernd Kräftner

This results in the practice to test every artwork for its use by the apparatus, but never the apparatus for its use by the artwork.
—Brecht 2003, 14

In August 2005 Caritas Austria, an organization that runs shelters for asylum seekers, circulated the following letter on our behalf:

In case you have been working as a scientist before you became an asylum seeker in Austria, we would like to ask for your attention. Maybe you are interested to participate in the following exhibition project. In the course of the Austrian EU-Presidency next year we are planning an exhibition project called "x06—Visions / Versions of European Research" that will take place in Vienna in June 2006. It is sponsored by three Austrian ministries and organized by Science Communications. This exhibition project consists of about 12 different modules, concerning the relationship of "Science and Society", displayed in multi-media installations and presented in different places in the city of Vienna during the show. One of the modules we plan concerns the situation of scientists that became asylum seekers.

In the run-up to the exhibition x06, we plan a project of approximately 6 months where we will try to provide office space at Viennese Universities to up to 10 scientists who live in Vienna as asylum seekers. Since it is not possible to employ scientists on a regular basis, they are provided with access to an academic environment. During the exhibition x06, we want to display their experiences and work in an "Office for Scientific Flotsam and Jetsam" and organize events to discuss the situation of all participants in the public.[1]

When the exhibition opened a year later, there was very little to see. Instead, an ever-changing group of fifteen to twenty-five asylum seekers and refugees[2] with academic backgrounds were present themselves to interact with visitors, tell their stories, debate refugee politics, or simply chat. Why did we shift from the promise of exhibition to interaction? In this chapter we discuss the dynamics of what happened during the making of the exhibition in terms of what we call incubations. We describe incubations as a process that aims to "invent the social" under pressure,

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as opposed to describing or criticizing it (Marres, Guggenheim, and Wilkie 2018). Incubations thus depend on methods to open up routinized procedures and situations. Such pressure, as we develop in this chapter, prompts the project to shift in fundamental and unforeseen ways. Notably, media and methods shift to the extent that the project moves away from recognizable and established STS methods and becomes radically performative and interactional. Following on our previous statement on the general logic of incubations (Guggenheim, Kräftner, and Kröll 2018), in this chapter we focus on the ability of incubations to encourage such shifts and the necessity to see them as a way to learn and expand the repertoire of what STS can be rather than to see them as a problem.

After expanding the notion of incubation, we describe the following shifts: First, the very focus of the exhibition shifted from migrants to refugees. Second, the space and location of the exhibition shifted from being mobile and at the periphery of Vienna to the center of the city, which created the preconditions for the subsequent shifts. Third, the originally intended methods of representation shifted from us interviewing the refugees to them interacting with exhibition visitors. Fourth, because of the shift toward interaction, the objects in the exhibition shifted from being documentary objects about the refugees to being provocations for interactions. Finally, our roles shifted from being curators and researchers to being managers and social workers.

The chapter is based on interviews with two participants in the project; our memories of the project; a large number of emails among ourselves; reports written for our clients as well as the exhibition catalog, which contains texts by the members of the Office for Scientific Flotsam and Jetsam (OSFJ); and an interview with the curators by the members. This is not a proper ethnography, because we lack the data to do this. Instead, we offer a post hoc reconstruction to explain the practical logic of these shifts as a specific kind of STS making & doing.

INCUBATIONS: INVENTING THE SOCIAL BY ENCOURAGING A PROJECT TO SHIFT

To begin with, let us clarify what we mean by incubations and how this relates to other ideas of making & doing STS. In a previous publication we defined an incubation as "a socio-technical device that uses situational, social and time-based pressure to invent the social and represent it with a wide variety of media" (Guggenheim, Kräftner, and Kröll 2018, 65–66). Let us stress here that this is an approach not only to represent the world but to consciously interfere in the world in order to make it anew, but without having a specific goal in mind of what this new sociality should look like. We have suggested that incubations need, first, suitable setups; second, some form of pressure to make situations malleable; and third, carefully designed products in adequate consumption contexts. In this chapter we trace the genealogies

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and affinities of this approach and then highlight why interrelated shifts of media and methods are crucial.

Incubations follow the call by Law and Urry to "enact" the social, an acknowledgment that all existing "theories and methods are protocols for modes of questioning or interacting which also produce realities" (2004, 395). For Law and Urry, this meant being attentive to the performative effects of methods; it did not imply a call for different methods. Others contributed observations of the inventiveness (Lury and Wakeford 2011) and messiness of methods (Law 2004).

More narrowly, in STS, and specifically in studies of public engagement of science, such calls have been used to counter the idea that public engagement practices are fixed, an idea premised on a view of citizens as blank slates (Lezaun and Soneryd 2007) rather than being "emergent and produced—as sites in which both publics and their views on technology are . . . ultimately intertwined" (Selin et al. 2017, 636). "Experiments in participation" (Lezaun, Marres, and Tironi 2017) are a further step to understanding participation as a performative practice in which STS researchers may actively intervene.

One way of intervening has been to focus on actor positions and relationships as emergent. Doing so, as Teun Zuiderent-Jerak points out, implies that STS scholars "can intervene in controversies in ways that do something different than re-iterate actor-positions" (Zuiderent-Jerak 2016, 74). Adolfo Estalella and Tomás Sánchez Criado thus call for "experimental collaborations" to renegotiate actor positions (Estalella and Criado 2018).

Experiments in participation are linked to a focus on "material participation" (Marres 2012) or "material deliberation" (Davies et al. 2012). STS researchers with this focus are often understood as moving away from the seemingly restrictive and exclusionary medium of text and toward "multimodal reinventions" (Dattatreyan and Marrero-Guillamón 2019, 221). Projects have brought together artists and STS researchers (Calvert and Schyfter 2017; Sormani, Carbone, and Gisler 2018), and STS researchers have worked with methods and material practices from the arts (Hatzius and Wakeford 2015), design or "critical making" (Ratto, Wylie, and Jalbert 2014; see also Wilkie and Plummer-Fernandez 2015), and architecture (Calvillo González 2018). What these approaches share is that they use objects and devices purposefully to elicit, change, and provoke novel forms of the social.

These projects often start and end with particular media and particular devices. This can amount to a reversal of the usual logic of STS, in which devices replace texts as the a priori medium of an intervention. There may even be elaborate sequences of methods and devices designed to elicit specific versions of citizens (for an instructive example, see the table in Selin et al. 2017, 640). They tend to read the analytic point of STS that objects and technologies literally "build the social" as an instruction for action through designed devices (Calvillo González 2018, 41). Instead of observing the power of design to shape the social, they harness this power for the uses of STS. These

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projects usually focus on a finished, clearly delineated object that sits at the center of practice and attracts and creates a public, such as bots (see Wilkie and Plummer-Fernandez 2015), or records the world, such as sensing devices (see Gabrys 2014).

Incubations follow more closely the original observation of Law and Urry of enacting the social as "modes of questioning" (Law and Urry 2004, 395)—that is, as an ongoing *practice*, a method and theory. Incubations, then, share assumptions of participative action research and participative design (Andersen et al. 2015; Binder et al. 2015; DiSalvo et al. 2011). However, participative design research usually begins with a normative position that takes certain end states (mostly broadly Marxist and socialist ideals) as goals and then devises methods to achieve those goals. Incubations however, do not start with such preconceived notions of a good society but, again, follow an experimental logic: "What it is to do good, what leads to a better life, is not given before the act. It has to be established along the way" (Mol 2008, 75).

To experimentalize notions of the good means to take seriously the ways in which methods and devices change how different versions of the social emerge. The goal, then, is not to deploy specific devices to create defined versions of the social but to explore new devices and methods to be able to explore new social formations. In incubations, new materials and methods are intentionally made to emerge together with and in conjunction with new formations of the social.

The project we discuss here is particularly suited for exploring how such an experimentalization of methods and media develops. In our project, a sequence of shifts led to new versions of researchers and new versions of refugees, along with the deployment of new objects and methods.

The focus on shifts highlights a crucial problem for STS researchers and identifies difficulties of doing incubations. STS is well versed in accounting for science in the making by not falling for post hoc rationalizations of actors. Yet projects of making & doing, such as those cited earlier, tend to produce well-elaborated points about how certain devices and objects that were developed by STS scholars contribute to ongoing theoretical concerns of STS, as if these devices were always designed to contribute to these concerns. This logic can be attributed to the fact that indeed many such projects were designed to contribute to specific STS concerns from the outset. It can also be attributed to the fact that such accounts, because they are autoethnographies, tend to streamline the development of a project to indicate such contributions.[3] We have done this ourselves for the same reasons (Guggenheim, Kräftner, and Kröll 2016, 2018). But here we attempt a reconstruction that pays attention to the sequential development of a project and its shifts. We advocate a particular method that allows for such shifts, and we attempt to understand what these shifts do to a particular project.

These shifts were possible only because of the way we set up the project and actively allowed them to happen. When John Law describes empirical research as a "mess" (Law 2004), he asks social research to allow for this mess. But incubations

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go a step further by asking us to attend to this mess in what we call "appropriate" ways—that is, by allowing the logic of the project to destabilize STS methods and media so much that they are no longer recognizable as social research. To attend to the logic of a project prioritizes both the contextual circumstances and the internal dynamics of methods and devices over disciplinary logic (this has been discussed as transdisciplinarity in a different intellectual lineage (Gibbons and Nowotny 2001). Note that this is different from situating the project or incubations in general as art, exhibition, or design projects, which would safely displace them outside of STS: to allow for shifts such as those described in this chapter assumes that incubations can move between these disciplines while becoming neither of them.

From the viewpoint of an incubation, the problem is not to accept messiness and then describe it but to develop ecologies of methods and practices that allow projects to shift with the complexity of the world. Incubations ask us to allow methods and media to shift along with changes in a project, rather than simply to register mess. This also echoes the "ecological" stance that "it is not possible to properly understand any one collective of participation without understanding its relational interdependence with other participatory practices, technologies of participation, spaces of negotiation, and the cultural—political settings in which they become established" (Chilvers and Kearnes 2016, 52). But again, for an incubation, the task is to go one step further, to move from *understanding* this "relational interdependence" to turning the STS researchers and their devices and methods into active and experimental parts of it.

For us, writing these shifts is tricky because reconstructing the distribution of agency between various actors and actants throughout the project is difficult. This is, first, because we were busy doing the project rather than documenting it. From this limitation also follows that the goal here is not, as in a typical ethnography, to give equal voice to all participants but to elaborate the practice of incubation. Thus, the documentation necessarily overemphasizes our viewpoints and underplays those of other actors. Second, any memories and reconstructions have to contend with the danger of either implicating a false teleology and overemphasizing our powers or giving an equally false impression of drift and being at the mercy of constraints that were not of our making. The reconstruction reminds us of the dual logics of how engineers account for technology: If everything goes to plan, they attribute this to the superior logic of engineering. If something goes wrong, they insist on the "unruliness" of technology that escapes their powers (Wynne 1988, 148).

1. VISIBILITY THROUGH HETERONOMY: FROM MIGRANTS TO ASYLUM SEEKERS

In the first shift, the project moved from focusing on academic migrants in general to being more narrowly about asylum seekers. This shift may seem innocuous, but only because the shift happened *after* the overarching exhibition was accepted by the

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contracting body could the project come into existence as the very unlikely incubation that it was. The shift allowed refugees to occupy a central square in Vienna where they could interact with the public, sponsored by and speaking in the name of a right-wing government. The project could produce a new formation of the social only because it was never planned to do so, neither by the contracting body nor by the project team.

How did we get license to work on a project with and about asylum seekers in the name of the Austrian state, which at the time was a coalition between the Catholic-conservative Austrian People's Party and the right-wing Alliance for the Future of Austria?

Although many interventionist STS projects start from a consciously chosen position outside hegemonic actors—and this is what we very often do ourselves—this was not the case here. Our beginning had a most unlikely starting point. When it was Austria's turn to take on the European Union presidency in 2006, a group of ministries[4] formed Innovative Austria and set up a competition to promote the Austrian innovation landscape through a program of public understanding of science.

Two of us (Kräftner and Kröll), together with Alexander Martos and Berthold Schütz from the research communication agency Science Communications, entered the competition with a two-part proposal (Guggenheim joined the project after the competition): first, and mainly, to communicate Austrian science to the public through a "long night of research,"[5] and second, to hold an exhibition.

For the competition entry, the exhibition concept was vague and did not contain any description of what would later become the modules. The reason we won the competition had less to do with the proposed exhibition than with the other, larger half of the project. It helped that we did not know what we wanted to do and that we could hide behind less "problematic" projects. We can only speculate, but if the sponsoring ministries had known the details of the exhibition, and specifically the module we describe here, they probably would not have awarded the competition to us.

After we won the competition, we faced the fact that there was only a budget—approximately 1 million euros[6]—and a vague description, but no actual concept, no team, and no location.

Two important decisions shaped the exhibition, and they went hand in hand. First, in the initial concept paper, "Visions and Versions of European Research," we couched everything in politician-friendly terminology but pointed to the multiplicity and transnationality of viewpoints that we wanted to showcase. Second, we wrote that we would focus on topics that cross barriers between disciplines, professions, and stakeholders. The visions and versions became a sequence of ten modules, each a mini-exhibition that focused on one topic or controversy.[7]

Initially, for the module we describe here, we wanted to address the migration of academics across national borders through student exchange programs, fellowships, and visiting professorships. In the first of two proposals, we wrote, "'Brain Drain' supplies anonymous brains with faces and contrasts the motives of temporarily or

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permanently emigrated researchers with images . . . about emigration . . . perpetuated by the media and science policy." We planned to combine this with a focus on "statistical migration." Neither of these proposals contained the term "asylum seeker," but both had a strong STS focus on the making of migrants through bureaucratic procedures and statistics, similar to current interests in STS (Dijstelbloem and Broeders 2015; Ruppert 2011). Similar projects underway in other European countries sought to bring migration—though not migration of academics—into public discussion.[8]

An accidental encounter with an academic asylum seeker in Vienna shifted our focus. Meeting him brought all the problems we would later encounter in our project to the fore: for him, being a professor was restricted to trying to reclaim a lost status rather than operational expertise, because these credentials could not be demonstrated in a radically different context. The tag "asylum seeker" silenced everything that made up his biography as an academic. We began to focus on giving a stage to this undiscussed migration of academics, thus shifting from the high end of academic migration to an invisible migration of academics. Shifting the topic toward refugees also moved the module away from a classical STS focus on the making of migration statistics, because academic refugees were invisible to and made invisible by the state.

At the beginning of the exhibition, we established an advisory board composed of senior academics, curators, and industry people. We presented a long list of modules to the ministries, and they urged us to abandon OSFJ. They thought the shift of topic undermined the very idea of how Austria wanted to represent itself to the EU. But we had negotiated with the ministries that the advisory board would decide on the selection of modules. The advisory board strongly supported the OSFJ module and the contracting ministries did not dare contradict the advisory board. Within its organizational context, the project could come into existence only because of its lack of definition at the beginning and was allowed to shift because of being protected by the advisory board. It was the radical lack of autonomy that allowed the project to gain the prominence that it eventually had. We could not have created the project were it not for having won the competition. Only because we decided to restrict our autonomy further through an advisory board could we defend the module against suspicious ministers. The pressure to abandon the project strengthened the belief that this module should occupy a central position within the overall exhibition and that it would give the other modules that centered on issues such as gene doping, peak oil, and environmental management a very different meaning.

2. THE SHIFTING OF THE SPACE: A LOCATORY FOR AN INTERVENTION

The second shift delineates how the project finds a physical location and, by finding a physical location in the center of the city, creates the conditions for putting face-to-face interactions at the center of the project.

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A textual STS does not need to think about its spatial location. Texts are mobile and have no defined home; they encounter their readers wherever a copy of a text happens to be. The situatedness of STS is usually enacted in writing, describing a place for an unrooted medium. An exhibition, however, is located, and its spatial accessibility and local context is a fundamental feature of its situatedness. Unlike writing, whose dissemination is difficult to predict and control, situating an exhibition in public space is always a decision between integration (blending with the environment) and intervention (sticking out) that relates the exhibition to its specific locational context (Kwon 2004, 56–99). As a place of intervention, an exhibition is a "locatory," a "place where specific knowledge-claims can be made, which are not possible in other places" (Guggenheim 2012, 111). A locatory in this specific case, we add, is a place where new interactions can emerge and new identities are formed that would not be possible in other places.

Once we had settled on the concept of ten modules, the question was where to position them. Initially, before we had shifted to asylum seekers, we planned to locate a module at the airport of Vienna, where it would be met by migrants of all kinds. Restrictions at the airport made this unfeasible. A later memo speaks of "book-busses in the countryside, busses of public transport, a truck, mobile homes." The modules, then, would themselves become mobile, a form of flotsam themselves. Finally, killing off the idea of mobile modules, we decided to locate each module next to a different station of the underground line 1, which runs right through the center of the city.

This module needed to be in the center of the exhibition. The lack of a suitable and available preexisting space in the center of the city next to a stop of line 1 prompted us to settle on a shipping container. The relative mobility of a container would enable us to put it anywhere we wanted—and were allowed to—and it would allude to global transportation.[9]

Karlsplatz is the main underground interchange, where four of the five underground lines intersect. On the square sits the Charles Church and next to it the Technical University. We convinced city officials to allow us to place the container between them (see figure 3.1). The prominent location also meant that our container would be seen by thousands of people, including tourists visiting the church, students and academics working at the university, and random passersby and visitors in the square. The exhibition of all ten modules was held during six weeks in June–July, free to the public, and seen by some fifteen thousand people.

While we were shifting the location of the module, we were still thinking in relatively conventional ideas of a documentary exhibition. But the location created the conditions to move the module away from being a documentary to being a place of interaction. The choice of location became an intervention regarding *the location of refugees* in the city.

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3.1 The container next to Charles Church; the Technical University is just outside of the frame to the right (the banner on top reads "Office for Scientific Flotsam and Jetsam").

3. SHIFT: FROM ETHNOGRAPHY TO PERFORMATIVE INTERACTION

The third shift was the most crucial and most radical one. Setting up the OSFJ *created* a new social entity. But this entity did not have its own, suitable form of representation. Over time, our methods shifted from preproducing ethnographic materials to ultimately relying on live interactions in the exhibition. This move was primarily a shift of medium, from documentary media such as video interviews to face-to-face interactions. But it also established a different agency of the refugees. Importantly, this shift was only possible because of the previous shifts detailed earlier and because the project was set up as an exhibition.

Before assembling the group, we had planned to represent their biographies with qualitative interviews, possibly recorded on video. This would allow documenting their trajectory from academic to refugee. Academic refugees, like all refugees, are determined in public by their status as refugees.[10] They are forced to live together in refugee homes, despite their differences in class, age, ethnicity, religion, country of origin, language, and so on. Refugee status is pressed on them as the only publicly visible classification at the expense of all other classifications. The members of the OSFJ came from Sudan, Côte d'Ivoire, Chechnya, Ukraine, Georgia, Libya, Palestine,

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Kyrgyzstan, Somalia, the Democratic Republic of the Congo, Afghanistan, Iraq, and Iran. Most did not speak German, and many did not speak any of the languages that we spoke (English, German, French, Spanish, Italian, Portuguese). They were doctors, engineers, agricultural scientists, social scientists, and linguists, among others.

How could we encourage and support them to represent themselves, through working as a group, when the only thing they shared was that they were forced to live in a refugee shelter and answered our call there? An important first step was to organize an actual office, in which they could work independently of us. We rented an unused café, around the corner from the exhibition team's offices. This was a first step to give the refugees space to develop their own projects outside the pressures of the incubation. It gave them a sense of purpose unrelated to the regular meetings we had. But it did not solve the problem of how to bring the group into the exhibition and how to turn their status into a matter of concern.

There was no shared object that could be externalized as an object of design and around which various audiences could be assembled, such as in the case of hybrid forums (Whatmore and Landström 2011). Work at the intersection of STS and design has highlighted the role of devices (Lezaun, Marres, and Tironi 2017; Wilkie and Plummer-Fernandez 2015) for the "collective articulation of issues" (Dantec and DiSalvo 2013; DiSalvo et al. 2011, 186). But such an externalized object did not exist. Rather, it was the members themselves who were the object of the exhibition, the matter of concern, and the personification of the issue at the same time. Expertise was located in personal experiences, similar to feminist health projects of the 1970s. But as the accounts of doing and writing such practices make clear, such work was highly skilled and developed over a very long period of collaborative research (Murphy 2012; Wells 2010).

We understood that some members of the OSFJ were reluctant to be interviewed—not least because being interviewed is related to the process of becoming a refugee. At this point, we shifted to the idea of them interviewing each other.

As Guggenheim put it, "I believe the interviews would be more interesting. Not: an ethnographer interviews a poor refugee, but rather an exchange of ideas and opinions. This would also make the camera less voyeuristic."[11] However, this simply compounded the confluence of person and issue and proved too ambitious, as already foreseen by Kröll in response: "There are inhibitions (communication among each other, technology, etc.). . . . There are also personal reasons (other than language and culture) why some do not talk to each other."[12] Interviews may have worked partly as a group-building exercise, but they did not work as material that could be used in an exhibition. Filming also brought the problem of anonymity to the fore. Some expressed their wish to be named, and others did not want to be.[13]

After a year of the members of the OSFJ working under precarious conditions, shuttling back and forth between a refugee shelter and our office, without even sharing a language, we learned that there was no straightforward method to produce

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the materials we initially envisaged. The longer we worked on the project, the more representing the members became a chimera, something weird and distant and out of tune with the operations of the OSFJ. The more we worked together and the more complex the stories of the members became, the less able we were to represent these stories. Without producing data in any meaningful sense (we did not take any notes of these trials), the data took a life on their own, which increasingly did not fit any display format that we could collectively imagine. Yes, we could interview some of them and put long interview excerpts as texts on the walls. But how would this work as an *exhibition*? We finally decided to abandon any attempt at narrative representation.

How then to incubate a topic whose main actors were both researchers and researched, but without a single object or device around which they could form a collective and without any medium and method of representation that worked? How to include actors whose only shared definition is that they are excluded?

Very early, we thought about how to connect the modules and how to deepen their topics without resorting to explanatory text. We decided to work with what we called "module carers." These were project members who cared for each module during the running of the exhibition. Most were students in STS, the social sciences, or the arts. Each carer would be a mixture of museum attendant, technician, and exhibition guide. We trained them to know about each module's topic, so that they could interact with visitors as guides through the objects and controversies on display.

For the OSFJ, we realized, we could turn the members of the OSFJ themselves into their module carer. This would not only give them a visible position but also solve the problem of representation. Module caring could become a way for them to tell their story, to meet visitors interested in the module and to hang around with their peers and other module carers. As Paula,[14] a member of the OSFJ and a trained medical doctor, put it in an interview, "Because I am an asylum seeker nobody talks to me. No one knows who Paula is and what she does. She is just an asylum seeker with dark skin, who does not fit in. But there we were as people. . . . I am seen as someone who is *here*."

Turning the members into module carers also changed the role of the latter: instead of being someone who involves visitors in discussions about the works of others, the module carer herself became the exhibition. For the visitor, the visible distinctions among an absent narrator of the exhibition, the present exhibition guide, and the exhibition subject collapsed. This, in turn, challenged the narration of the exhibition, because any stable narration vanished. No one had control over the story that emerged from the module. The story depended on whoever was working as a module carer on any given day and that person's interactions with the visitors. The story would also change along with the changing experiences of the members as asylum seekers and how their interactions with the visitors played out. It also changed us as a collective. We curators became ever more insignificant as authors. Members

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stopped being resources in the background and became devices to spur interactions. The module itself became the medium to change their existence. The exhibition did not turn them into an issue over which they had control; it made them literally move themselves and the issue into the center of the city, a shift that would not have been possible if this were not an exhibition.

4. SHIFT: FROM EXHIBITS TO PERFORMATIVE OBJECTS

The fourth shift builds on the third shift toward interaction. All modules depended on module carers to connect exhibition objects and visitors. However, in the OSFJ the carers would have a different relationship to the exhibits. The interaction between carers and the visitors would be the center, and any object would be at the periphery of this interaction. Thus, once interaction rather than representation became the purpose of the module, the role of objects within the module began to shift as well. Objects would not need to be equipped with the power to be self-explanatory or even intelligible without being part of an interaction. There would be no need for contextual information. Objects would become either infrastructure or triggers for interactions.

Our idea of an exhibition was based on an understanding that has emerged through working at the interstices of art and STS with various media and their "alien agency" (Salter 2015). The members of the OSFJ did not share these ideas about exhibitions. None of them had experience in this field, and many imagined exhibitions as visual art hung on walls. The shifts recounted in the previous section earlier were problems of representation and recording and relatively easy to understand for the members. After abandoning documentary materials, we still had a container, which needed to be somehow designed as an exhibition. Because we did not want to override them with a complex translation of their situation into an installation, we turned back to the most basic elements of their lives.

From the beginning, the BA, MA, and PhD certificates of the members occupied a special place in the project. Certificates are one of the few objects asylum seekers hold on to. More than money, they are promissory objects that preserve and transport status to a new place. But as soon as refugees arrive in Austria, they realize that these documents are devalued. Certificates of asylum seekers are ignored by state bureaucracies. Once granted asylum, their certificates are often not recognized. Even if they are, they are unlikely to be given much currency on the job market (for Austria, see Eggenhofer-Rehart et al. 2018; for an overview, see Martin et al. 2016).

As one member put it in an essay for the catalog: "At home [in Somalia] I worked for international and local organizations as University teacher, journalist and teacher of journalists. . . . . Despite my qualifications I could only work [in Austria], humiliated, as a builder." Documents endowed with all the signs of the state and all the technologies of making a document official suddenly lose their power in a world that seemingly is built around the power of precisely such acts of official certification.

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3.2 Cartoon by Vaheh Abram, a member of OSFJ.

The humiliation of having to work as a builder is compounded because academics are more than anyone else living with a *belief* that such certifications represent skills and knowledge that can be translated into jobs and money (see figure 3.2 for a cartoon referring to that topic by one of the members).[15]

This belief is reinforced by the design of certificates. Each of them is not merely a piece of paper conferring a qualification to a person through a text but an elaborately designed claim to official power, through the use of ornaments, fonts, seals, and signatures by important people.[16] We decided to exhibit copies of these certificates both to demonstrate how these performances of visual officialdom become worthless and to make them potential starting points for a discussion between module carers and visitors.

First, in a move that was echoed by Whatmore and Landström (2011), we decided to use objects to spur conversations. We asked our carers to bring in objects that they wanted to have in their office. These included a white doctor's coat, brought by a member to represent her inability to practice her profession,[17] and a Somali-to-German dictionary of medical terms that one of the members had compiled to help other refugees.

Second, we wanted to turn the office into an actual, usable office, not only to make a statement about the precarity of the working conditions in refugee camps for the members of the OSFJ, but also to allow them to use the exhibition as an actual

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3.3 Inside the container.

office and meeting space.[18] Thus, we brought in secondhand office furniture that would allow people to sit and talk as well as work.

Finally, one of the members had the idea to include maps of their origin countries. We bought a map for each country and used it as wallpaper on the ceiling (see figure 3.3). The final effect was disconcerting: the room was a usable office that looked like an office in a building circa 1980, except for the maps on the ceiling and the copies of certificates. But it worked extremely well throughout the exhibition, precisely because it did not focus the attention of visitors on the visible but only provided starting points for discussion.

5. SHIFT: FROM THE OSFJ TO RESEARCHERS WITHOUT BORDERS

Once we focused on refugees, our module also began to shift away from being solely an exhibition. Although the previous shifts can all be reconstructed post hoc as inventing the social as a form of representation, this final shift literally created a new social entity. The OSFJ became an independent formal organization that would connect refugees and academic organizations. But ironically, the new organization became a provider of a form of documentation that the project initially had set out to abandon.

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As we became aware that involving the members in documenting their status and biographies might be both difficult and not what they might think was the most pressing issue, we considered how we could document their situation by changing it along the logic of the exhibition. Even if the certificates were worthless, the members still had skills. We decided to set up a kind of exchange and training scheme, in which we would pair refugees with relevant academic organizations. We thought we would document the workings of this training scheme in the exhibition. We quickly found a small number of professors who were willing to help and host people. But in the event, most members went not to universities but to para-academic organizations, hospitals, and companies. The mentoring program was mostly run by Kröll and included searching for a suitable place for each person. The incubation, and Kröll's job in particular, shifted from being an observer and curator to also being a manager, social worker, and lobbyist.

For bureaucratic reasons, this process proved to be incredibly slow. Because of the varied discipline, language, and professional skills of members, we had to look for tailor-made arrangements. No legal framework existed, and no existing organizational setup could be used for all of them. There were numerous bureaucratic obstacles, such as the problem that asylum seekers, who could not be employed, did not fit existing organizational categories and could not be insured. These problems delayed placements until after the opening of the exhibition and made documentation for the exhibition impossible, which exacerbated the documentation problems within the exhibition referred to in the previous shifts.

Attempting these placements also allowed the members of the OSFJ to emancipate themselves from our project. They did not need to identify with the complexities of the exhibition or the demands of a collective they did not choose to be part of. When we discussed the option of founding a new association in order to continue the visibility of the interests of asylum seekers with an academic background, some of the participants expressed a concern with representing themselves as "scientific jetsam and flotsam." Together, we finally agreed on the name Researchers without Borders for the new association.

The mentoring program could become permanent and independent of the pressing timelines of the exhibition. It also allowed us to set up a network of alumni of the OSFJ that would have the means to come together once their status had been regularized.

Eventually, we would write letters to the asylum authorities to bolster our members' claims to be integrated into Austrian society: "Since 2006 Miss X is a member of the association 'Researchers without Borders.' She has participated in various activities of the association including weekly German conversation groups. Miss X is an active member and contributes with her organizational and communication skills to various events." Being a member of an organization that was founded to compensate

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for the active exclusion of asylum seekers by the authorities became proof of being an integrated asylum seeker.

Not documenting members' biographies and subsequently inventing new ways to interact with audiences for an exhibition led us to document members' lives in the most prosaic and bureaucratic ways for the authorities. This may be the most surprising aspect of the project, once we accept it not as disconnected but as part and parcel of a trajectory of an incubation. When we began the project, we thought that as STS scholars we would document the knowledge practices of how states make migration. The knowledge that we collectively gained about the situation of refugee academics did not become a theorization or documentation but was operational in a way that was both unforeseeable and surprising. It created a new kind of STS making and a new kind of academic refugee who documents herself by being herself in public. By being herself in public demonstrates the right to become a citizen.

CONCLUSION

To conclude, we would like to highlight a few points that allow us to situate an incubation as a form of STS making & doing and why it is so unlikely and difficult to make it happen. As pointed out before, all shifts are connected to each other. For narrative convenience, we have separated these shifts. But the development of the project meant that changes of the topic led to changes of the location. This in turn led to changes of how the group understood itself and to changes of our role and of the media and methods used.

First, the incubation depended on the organizational possibility that these shifts could happen at all. The incubation needed funding that would allow us to make these shifts. Under normal funding rules for research projects, it would be impossible to begin without knowing what the project would be and then to continue to radically change the project along the way. It is even harder to imagine research funding made on a promise to do research, only to abandon that research in order to allow asylum seekers to interact with the audiences and to start building a nongovernmental organization.

Second, the incubation implies that we as curators would be able to do these shifts. We needed to have the time and the institutional freedom to do so, without the fear that we would be lost without proper training or disciplinary guidance. We could do this only because we were not accountable to university departments or funders that would demand an academic contribution to a field.

Third, we needed the skills to make these shifts or, at least, the lack of fear that we did not have these skills. *STS* making & doing sits here in tension with establishing STS as a distinct *academic* discipline (even in its activist versions), which is based on a set of teachable methods, and the affordances of incubations. Incubations are demanding precisely because such definable skills are needed, but another

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set of different skills that are *unknown* at the start of the incubation are needed as well.

Finally, there is a performative irony underlying this chapter: it seeks to contribute to STS making & doing by moving away from the making and doing itself and accounting for it in a medium that was abandoned in the making & doing of the project we report on here. The logic of an incubation, as we have detailed previously, asks the project to allow for radical shifts to find a form and medium that suits the project. In this report, this logic is inverted and the project is forced to leave the form and medium that suited it, to conform to the logic of written STS. The report itself is temporally, spatially, and in its form far removed from the project. It also differs from the exhibition catalog, which contains articles by the members of the OSFJ, including their interview of the curators (Guggenheim et al. 2006). In this chapter, only the curators report on the project. This is so because the other members of the OSFJ have dispersed, do not have time, and most importantly, have neither an interest in nor the skills to contribute to STS discourses. It is not an oversight or a lack of collaboration or participation that they are only spoken about here. It is a direct outcome of the media infrastructures of STS that the project shifted away from. The radical difference between making & doing STS and accounting for making & doing in an STS idiom, however, should not lead us to try to render the making & doing itself more like the accounting for it. Quite the opposite; to create good incubations means to let them shift as far away from STS and its media infrastructures as needed and feel confident that the accounting for it is a second, separate act.

ACKNOWLEDGMENTS

We would like to thank the editors and Lucas Becerra, Paula Juarez, Max Liboiron, Monika Krause, and Melissa Nolas for their generous and extremely helpful comments. We are indebted to everyone who participated in and helped us with the exhibition, especially Alexander Martos, who was our partner in this project.

NOTES

1. The text was written in English. It is reproduced here without correcting any grammatical errors. Other sources cited are translated from German to English by the authors.

2. We distinguish between "asylum seekers," or those who are applying for refugee status, and "refugees," or those who have been given refugee status by Austrian law. This difference has important consequences in Austrian law for access to financial support, housing, and the right to work. In the United Nations definition, "refugee" includes both groups.

3. But see Calvert and Schyfter (2017), Michael (2012), and Sormani, Carbone, and Gisler (2018) for actual ethnographies.

4. These were the Council for Research and Technology Development; the Ministry for Education, Science and Culture; the Ministry for Transport, Innovation and Technology; and the Ministry for Economy and Work.

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5. Long nights of literature, art, poetry, or research are an established popularization format in European countries to showcase cultural production throughout a single night. In the Long Night of Research, universities and private laboratories in Austria and Germany open their doors to the public and showcase their research.

6. To the uninitiated reader in a university, this may look like a lot of money for a two-year project. But we had to pay for everything, including rent for our offices and exhibition spaces and ultimately for around seventy people—curators, project members, project managers, location managers, exhibition guides, and security—and all exhibition materials and printing.

7. The other modules were (1) International park: research at the edge; (2) Caring for body and soul/vegetative state: What is a body/a person?; (3) Stained perception: Is there life on Mars?; (4) Who with whom? Inheritance in action; (5) I've got something: Allergy playground; (6) Gene doping: A difference that makes a difference; (8) Peer reviews: The scrutiny of scientists' performance; (9) SPeak Oil: The end of petrol, or the refined soul; and (10) Self-Service: Luncheonette for advice and other experiments.

8. For a recent overview, see Berlinghoff, Rass, and Ulz (2017).

9. In hindsight, the choice of the container was too predictable. Containers have worn thin as symbols for globalization. Our container also referred to a previous project with asylum seekers in Vienna. In 2000, as a protest against the right-wing Freedom Party of Austria, the German artist Christoph Schlingensief created "Please Love Austria." He set up a container with a banner that read "foreigners out." In an imitation of the TV series *Big Brother*, a group of asylum seekers lived in the container and the audience could vote on who to deport next (Bishop 2012, 280–283).

10. The situation of the people we worked with was also notably different from the far better-researched situation of famous refugee scholars such as those who fled from the Nazis (Bentwich 2012; Coser 1984; Fleck 2007) or those who fled communist states during the Cold War. Many of these scholars had preexisting international networks to help them and could *comparatively* easily continue their work in other countries. Very often, powerful organizations helped them establish themselves as academics (Tournès and Scott-Smith 2017). Academic literature focuses on such cases in part because they allow discussion of the exchange of important intellectuals and researchers, rather than stories of "irrelevant" academics who would never feature as subjects of history of science and technology (Abramson and Dolunay 2017). Further, it is much easier for refugees who flee to countries with which they share a language and, usually because of a history of colonial dependency, a history of academia (for the case of Algeria, see Leperlier 2018; for a historical comparison of such cases, see Pries 2017).

11. Email correspondence from Michael Guggenheim to Judith Kröll, February 22, 2006.

12. Email correspondence from Judith Kröll to Michael Guggenheim, February 22, 2006.

13. Email correspondence from Michael Guggenheim to Judith Kröll, and from Judith Kröll to Michael Guggenheim, March 27, 2006.

14. All members of the OSFJ are given pseudonyms.

15. Here is a problematic aspect of the project: By stressing the humiliation through the loss of the power of certificates, we also buy into the power that these certificates have. We could ultimately be seen as endorsing the fact that other asylum seekers, who do not hold certificates, deserve to be ignored by the local job market. Obviously, this is not a position that we condone. We thought that we could accept this risk, given that the whole exhibition was focused on science and not on migration and the labor market.

16. For a study of how design builds authority, see Deville (2015, chap. 5).

17. This anticipated the recent trend of artists to exhibit leftovers of refugees—for example, Thomas Kilpper and Massimo Ricciardo's project "Inventories of Escape" (2015–2017) or Ai Weiwei's

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"Laundromat" (2016). But these projects are ultimately voyeuristic and sensationalist because they divorce the objects from the refugees and leave the latter absent and voiceless.

18. We lost the room we had rented before the exhibition opened.

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4

DEEPENING THE FIELD, RAISING THE STAKES

Generating Technologies for Inclusive and Sustainable Development

Hernán Thomas, Lucas Becerra, and Paula Juarez

Members of the Sociology of Technology and Innovation Area of the Institute of Science and Technology Studies of the National University of Quilmes (the Quilmes team), Buenos Aires, remember 2009 as a turning point. In that year, a group of researchers began to transform their research praxis. The transformation included a series of analysis objects and questions, new ways of engaging nonacademic actors, and explicit political positioning regarding a positive intervention in the dynamics of inclusive and sustainable development.

Little over a year earlier, the Ministry of Science, Technology, and Productive Innovation (the S&T Ministry) had been founded with the goal of "deepening a productive and social development model based on generating value through knowledge."[1] The government's promise to invest in science and technology to create greater social and economic well-being confronted a lack of specific public policies and tailor-made management instruments. What could it mean to deepen a productive and social development model? In particular, what science and technology (S&T) policies could possibly generate inclusive development processes in a country that had undergone thirty years of destruction in its productive matrix, a systemic downgrading of innovation, and significant increases in unemployment and structural poverty? Would it be possible to develop technological solutions for what were widely considered to be the chief social issues in Argentina—for example, lack of access to drinking water, housing, and energy; high costs of medication; and prevalence of regional diseases that still had no cure? These were some of the issues that officials wanted to solve, leading them to invite us to take part in the public policy design process for the new ministry.

We were convened as advisors to help design public policy instruments for science, technology, and innovation (STI) that could generate technological solutions to social issues. The invitation appeared to us to be two faces of the same coin. It

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was a remarkable opportunity to influence the design of public policies. At the same time, it posed a clear challenge to our knowledge, ways of learning, and practices as STS researchers.

We saw in the opportunity the possibility of generating policy instruments for STI that might, by design, avoid some problematic features of the praxis of knowledge generation in Latin America. Three of those features can be summarized as follows:

1. The generation of knowledge in Latin America (Argentina in particular) takes place within an agenda of topics and issues generated exogenously. S&T agendas in the region have barely focused on the needs of the local population. A vast literature describes the relative neglect of social agendas by leading R&D institutions (e.g., Albornoz 1990, 1997; Bisang et al. 1995; Dagnino, Thomas, and Amilcar 1996; Kreimer 1996; Oteiza 1992; Thomas and Dagnino 1999; Vaccarezza 1990; Vessuri, Díaz, and Teixeira 1984).
2. Problem-solution dynamics usually aim at realizing profits through relative market monopolies (Rosenberg 1982; Schumpeter 1928). Innovation is reduced to generating new merchandise rather than satisfying social and environmental needs (Becerra and Thomas 2017).
3. The praxis of technological development continues to be ruled by the linear innovation model, leading to a supply-side focus both in establishing the agenda of issues and in generating solutions (Thomas 1999, 2007, 2008a).

As a coconstructed process, these opportunities reflected challenges we faced yet presented them in a different ontological order. Could we be researchers looking for critical analysis and informed academic discourse, but also working with other social groups (e.g., policy makers, practitioners, social movements, and civil society entities) in order to produce solutions for social and environmental problems? The question "How is a local agenda of issues constructed?" is not just a question about how others work. It also concerns how we make a local agenda. At the same time and in the same way, could examining the legitimation of a policy process in terms of different relevant social actors (academic community, sources of financing, decision makers, and so on) be related to preserving our own political, theoretical, and ideological positions?

If it is possible and, indeed, necessary to operate with non-Schumpeterian rationales of development and technological change in order to make social development processes more dynamic, how can that be achieved? Are the theoretical concepts we have to inform public policy sufficient? Are they adequate? And again, as a twofold dynamic: Are there other researchers who failed when facing the same or a similar situation? And if they failed, why? Was it due to theoretical, political, ideological, or practical reasons? Is it possible to confront and deal with an entire system of research evaluation that doesn't, in fact, care at all about such matters?

Finally, if we accept the idea that technology is not neutral, is not deployed linearly, and does not work in the same fashion at all times and in all places, is it possible

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to develop public policy actions that manage not to fail? Might it be possible to develop a dynamics for producing nonapplied applicable knowledge? That is, could we produce knowledge we could defend as applicable but not applied because its production was responding to a specific local need or demand (Kreimer and Thomas 2003, 2004; Thomas and Kreimer 2002)?

The main goal of this chapter is to share the experiences and present the lessons generated when we researchers in the STS field put ourselves through this twofold concrete action that produced in our research work a dynamic transformation. We want to stress in particular that, in a coconstruction dynamic, the problem agenda, knowledge generation, and researcher concerns and activities, and also the very notion of what a researcher is, changed. Using a reflexive methodology, we analyze a set of concurrent dynamics that produced the transformative dynamic of making & doing in the Quilmes team: a modification of the research agenda and generation of new concepts and a transformation of researcher praxis, integrating design skills in public policies and as direct, on-site implementers of those public policies.

The analysis explores the experiences of one team in designing and implementing the Right to Access to Goods: Water for Development (DAPED) project (hereafter known as the water project). The water project sought to generate actual dynamics of local development in very poor rural regions of the Argentine north, starting with access to water. It also sought to produce a laboratory for the design of new public policies and public instruments for two national ministries. This work became a partnership between the National University of Quilmes and the National Institute of Agricultural Technology (INTA), with the support of the S&T Ministry and the Ministry of Social Development. We offer this case because the researchers involved bore direct responsibility for executing the local development project and for linking the knowledge generated in the field to the design of future policies.

DEEPENING THE FIELD: FROM RESEARCH OUTPUTS TO DIRECT INTERVENTION

In an ideal situation, informing a public policy on any subject in which a research group is working would be the result of a mature research process. That is, if we assume an ideal and linear world, research comes first, new concepts based on empirical analysis are produced, and then research results are produced (papers, books, conferences), and that knowledge is transferred to the public or private sector, which needs the new developments.

However, in concrete actions, events do not (cannot) develop following that linear order. In practice, a coevolution takes place in which issues to be solved stress existing knowledge; agendas are modified as communication and negotiation mechanisms are established between researchers and policy makers; and what stakeholders understand as "desirable/undesirable, possible/impossible, and existent/inexistent" (Therborn 1987, 75) is reconfigured as actions are deployed.

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In 2009, policy makers in the S&T Ministry presented the mission as an institutional deficit. The new ministry lacked an action line in its mandate for generating knowledge-based social development mechanisms. They wanted to rectify this absence. The emergent solution, presented against the backdrop of established practices for institutional policy making, was to create new programs or adapt existing funding. However, through a collective evaluation involving ministry officers and the Quilmes team, all came to understand that any actions taken would require a clear definition of the hierarchy of issues (to identify the ones that would receive public funding), the types of policy instruments to be used, the concepts for addressing the desired actors, and the criteria for assessing the results of new policies.

In our case, while the Quilmes team had research experience and academic production regarding STI in public policies (for example, about the S&T public policies deployed in Latin America during the twentieth century), we had a more traditional STS agenda geared toward historical analysis of S&T. Examples include the treatment of smallpox along the Río de la Plata during the eighteenth century, the production of slave ships in the nineteenth century, and the development of the Argentine metalworking industry in the mid-twentieth century. The new research team was led by a senior researcher with a PhD in S&T policy[2] and consisted of five PhD students working on issues related to the history of technology and two who had some fieldwork experience with appropriate technologies.[3] With this configuration, the team faced its first crossroads. If team members were to design new STI policy instruments—something we saw as desirable—what needed to happen within the team to make this happen?

Two possible roads lay ahead. The more traditional option was to provide a standard consultancy service of analyzing the client's issues and generating cognitive inputs to solve them. This was the simplest option. However, it has few feedback mechanisms and limits the team's potential capacity to codesign and follow up the policy, which limits the team's ability to learn from the experience and reorient (at least partially) the policy actions.

The second, more radical, option was to alter the whole orientation of the team's work. Transforming the research agenda in order to develop a series of studies with an empirical base and new concepts might make it possible to codesign STI public policies in more structural terms. Such a change needed two conditions: (1) the team's continuous and lasting involvement in policy processes, given that research work creates long-term results (compared with traditional consultancy); and (2) creation of inputs used in the research process to generate intermediate results that would dynamically nurture the policies.

Facing that crossroads, the strategic decision became an ideological definition (Therborn 1987) in the sense that there are no good or bad decisions from a rational point of view regarding technological, social, and economic development in society, but rather desirable or undesirable definitions based on a political positioning.

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We chose the radical option. This led to two dramatic actions at once. The first was to modify the research agenda toward creating useful answers for policy making—that is, how to design, produce, manage, and assess technological development policies for solving social and environmental problems. The second was to transform the researchers' praxis in order for it to have an influence on the design of public policies and to generate institutional articulation mechanisms, with the goal of strengthening and broadening the scope of our actions.

MODIFYING THE RESEARCH AGENDA

To orient a research agenda toward the resolution of social and environmental issues is no trivial task. We had to bear in mind that the agenda should enable academic production in order to meet the evaluation requirements of the S&T institutions in which we worked. In addition, research results should inform policy design. And the team needed prior concepts and discussions (economic, academic, political, and social) to construct interactions, in some cases as partners and in others as rivals.

The team gradually integrated these three issues in dynamic terms through two continuous actions. The first involved moving from an agenda of topics to one of research problems. The second was to construct a critical analysis of approaches for technology inclusion and to devise an organizing concept to be used as a lighthouse.

CHANGING THE AXIS FROM TOPICS TO PROBLEMS

In these first years of the twenty-first century, Latin American countries have been posting positive data about economic growth. However, alarming social and economic indexes reveal underdevelopment. Huge sectors of the population (between 20% and 50%, depending on the country and the indicator) suffer from shortages of housing, food, education, and access to goods and services. Argentina is one of the more dynamic Latin American countries in social and economic terms. The country has grown almost constantly since 2003 and shows improvement in several social indicators, such as poverty and unemployment, and in access to basic services and primary education. Yet inequality persisted in income distribution and structural deficits, including decent housing, transportation, access to sanitation and energy services, and environmental problems.

Housing in 2010 in urban areas, where 70% of the population lives, had a total shortage of 660,000 units, or a deficit of 8.7% (Centro de Estudios Legales y Sociales [CELS] 2010). Moreover, although most urban households in Argentina (98.9%) had access to drinking water, only 64.2% had access to a sewage network (CEPAL 2010). Also, even though the country is one of the major food producers in the world, Argentina had a food deficit affecting 5% of the population in 2005–2007, according to data from the Food and Agriculture Organization of the United Nations (FAO 2011).

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Examining these data led the Quilmes team to think about how to construct technological solutions that could be adapted to existing problems and resources. The technological complexity of housing-, water-, food-, and health-related social issues presented a window of opportunity for new types of interventions in new spaces. The conversations were long and difficult, however, because these issues differed greatly from those team members had worked on in 2008 and 2009. Still, the research agenda moved toward the priority issues of food, water, energy, health, and housing, and who might be expected to use research results.

Policy making requires more than an analysis of the energy sector, housing, or access to water and sanitation or framing questions such as "How is habitat produced in Argentina?" The design of public policies relies on research into technological development alternatives that may or may not produce inclusive dynamics or exclusionary processes. Thus, the archetypal question becomes: How and for whom does the development of artifacts, processes, or technological systems work or fail to work in addressing and solving a given problem?

Consequently, in concrete terms, the change of agenda meant that team members would have to formulate new research projects, applying for financing that rewarded research and the generation of public policies. The institute would have to reconfigure the master and doctoral theses of researchers in training. The team would have to integrate new types of members.[4] Team members would have to reconfigure their strategies for scientific publication. And the team would have to develop an institutional communication strategy aimed at challenging political and social agents.

During this first phase, one of the most important initiatives was creating the Network of Technologies for Social Inclusion (RedTISA). RedTISA brought together a collaborative network of public and private institutions aimed at strengthening and improving the capabilities of innovation and technological development for social inclusion. It was coordinated by the director of the research team (Hernán) and one of the research fellows (Paula) together with an official from the S&T Ministry and representatives from social organizations. The ministry official led the Program-Council of the Demand of Social Actors, founded in 2008, which approached the Quilmes team to design a call for proposals for projects aimed at solving social issues.

The main idea behind RedTISA was to fill an enormous gap in institutional coordination.[5] It assigned itself the responsibility to organize, coordinate, and integrate a diverse collection of public and private institutions and organizations (universities, nongovernmental organizations, labor cooperatives, research and development centers, among others) that wanted to contribute to the country's social inclusion and sustainable development. In this sense, it provided a collaborative platform for leveraging at a national level actions, insights, and recommendations generated by the Quilmes team and other members of the network.

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GENERATING THE CONCEPT OF "SOCIAL TECHNOLOGICAL SYSTEM"

In moving from topics to problems, we needed a theoretical framework to guide our actions in the field. We wanted use knowledge from our STS research to avoid problems that other groups and social movements had encountered when attempting to incorporate a technological dimension into strategies to solve problems associated with poverty, exclusion, and underdevelopment. We understood that technologies already play key roles in processes of social change. They outline actors' positions and behaviors, condition social and economic structures, generate processes of capital accumulation and income redistribution, enable or restrict access to goods and services, and create social and environmental issues and facilitate or hinder their resolution (Thomas 2009, 2010, 2012). A commitment to technologies for social inclusion emerged as a way to develop and implement technologies aimed at generating sociotechnical dynamics for social inclusion and sustainable development.

Framing technologies as a way to address poverty, exclusion, and underdevelopment had started in the 1960s with an interest in producing "appropriate" or "intermediate" technologies (Schumacher 1973). In general, technologies classified as such were of small scale (household or community) and low complexity, and drew on mature technologies, low levels of scientific and technological knowledge, low levels of investment, and low-cost inputs, with little or no relationship with the market. Yet most of these experiments had been interrupted, had failed, or had led to significant unwanted effects (Thomas 2009). In the 1980s, authors such as Rybczynski (1980) and Ahmad (1989) sought to get past the technological determinism of appropriate technologies, giving rise instead to "alternative technologies" (Dickson 1980). Over the next decade, new approaches emerged against the theoretical backdrop of the "economics of technological change," "grassroots innovation" (Gupta et al. 2003), "bottom of the pyramid" (Prahalad 2010), and "social innovations" (Martin and Osberg 2007). Nevertheless, each of these conceptual approaches had significant limitations that led to dysfunction and unwanted effects in their implementation. In addition to technological determinism, some of these effects included supply-side rationales, voluntarism, paternalism, nonintensive use of scientific and technological knowledge, lack of use of tacit and customary knowledge, inefficient use of economies of scale, specific solutions rather than systemic ones, misunderstanding of market relationships, and limits to market dynamics as the exclusive avenue for economic relationships (Thomas 2009, 2012).

Researching these critical outcomes became part of the group dynamic in the earliest stages of the new Quilmes team. Team members needed a concept capable of guiding the design and implementation of public policies for technological developments that directly addressed the dynamics of inclusion and sustainable development. This concept had to be a starting point, of course, a catalyst of coded knowledge for learning-by-doing experiences that could prove useful to the design of policies. The Quilmes team used the idea of "social technological systems" (Thomas

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2012)[6] to guide its work. Social technological systems aim at generating dynamics for social and economic inclusion. Heterogeneous in terms of actors and artifacts, the sociotechnical dynamics of social technological systems democratize technological decision-making and sustainable development. The concept implies actions for the design of products, productive processes, and organizational technologies that focus on inclusive problem-solution relationships, especially the socialization of goods and services, democratization of control and decision-making, and empowering of communities of producers and users. The actions of social technological systems simultaneously pursue four sociotechnical commitments required for socially and economically inclusive development processes:

- achieve equality of rights
- dignify conditions of human existence
- generate new spaces of freedom
- improve standards of living

Yet how could such a concept become praxis? A theory of social technological systems cannot itself find concrete existence without a series of actions to develop technological solutions aimed at inclusive and sustainable dynamics. Such dynamics would not be the result of spontaneous generation. The research team would have to orient its actions toward the field of policy.

ADDING THE ROLES OF POLICY DESIGNER AND POLICY DOER TO THE RESEARCHER'S PRAXIS

In 2009, the National Council of Social Policies—an interministerial agency—decided that a strategic policy objective would be to provide access to water uncontaminated by arsenic in the Argentine territory and entrusted the S&T Ministry to carry out the objective. The ministry called on the Quilmes team because it was already working with the ministry on technologies for social inclusion.

About 80% of Argentina is arid or semiarid and almost 40% has high concentrations of arsenic in the groundwater. The national government had financed numerous research and technological development projects to solve the arsenic problem, without success. The first item for the Quilmes team to negotiate was the focus of the initiative. Might it be possible to move from working on access to quality water to addressing local systemic development as a problem of innovation and technological development (DAPED 2012)? This proposal met with no resistance.

The team proposed a project with the assumption that the S&T Ministry would execute it. However, once the general guidelines of the project were constructed, ministry officers said that the ministry did not possess planning or implementation capabilities in the territory. The ministry refers to itself as a policy and funding agency, not as one that does concrete work in the field. The question became who would execute it.

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S&T Ministry officers were quick to argue that the Quilmes team should be part of and, indeed, coordinate the project. And given that there was interest from the Ministry of Social Development and from the INTA, the Quilmes team proposed that these administrative units establish a public-public consortium to implement it. That's when several political and bureaucratic problems began.

The S&T Ministry had intended to finance this initiative through a National Sector Fund for social development, using Inter-American Development Bank funds. It would charge the National Agency for Scientific and Technological Promotion to deliver the funds. This body had never financed a public consortium, however, and had also never provided a fund oriented to social development. There was not even a form on which to submit a proposal with these conditions. The problems quickly multiplied. As but one example, between 2009 and 2012 the S&T Ministry changed the project form twenty-one times, requiring the Quilmes team to present twenty-one different versions of the project. During these four years, there were several times we thought we would never get to do the work. After five years of negotiations with all parties, we finally got funding for the project. The S&T Ministry had initially called the Quilmes team a provider of technological "solutions," narrowly defined. During those five years, it became clear that providing solutions necessarily included challenging, reframing, and overcoming a range of bureaucratic barriers just to get the project started.

The team's first lesson was thus that, even with the political support of the Inter-American Development Bank and the highest national authorities, state bureaucracy lacked flexible procedures for intragovernment articulation and the financing formats needed to articulate and coordinate actions between government agencies. Not even a project implemented by two public institutions found space in government financing forms.

Although we were part of the government, we were excluded from the bureaucratic protocol, which impeded our ability to secure financing. The situation was solved not because the government procedures were amended but because, as nongovernmental actors, we managed to persuade the political stakeholders of the project's strategic importance to the S&T Ministry for future innovation in social development. In March 2014, the water project was finally born. It had an implementation unit (the Quilmes team and the INTA); it was supported by RedTISA, the Ministry of Social Development, and the National Council of Social Policies; and it was financed by the S&T Ministry. This marked another transformation of the Quilmes team, in this case adding the roles of policy designer and policy doer.

The water project had three objectives:

1. To generate a new mode of government intervention for improving the institutional capabilities of innovation and technological development aimed at sustainable inclusive development based on social technological systems;

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2. To ensure access to goods and services in rural communities significantly lagging in development—prioritizing access to water, both quality and quantity—through adequate technological systems; and
3. To design intervention, education, and research models to enable the scaling up and replication of these experiences at the national level.

The scientific and technological challenge was explicit, and the priority was to learn in order to improve government intervention models of comprehensive development.

Project implementation began in March 2014 in five rural areas of the province of Chaco. Each area had distinct characteristics. Some were indigenous communities; some were areas with low-capital farmers or family farms; some had populations of goatherds, vegetable producers, or brickmakers; and some had water with arsenic and salts, low flow in local waterways, or agrochemical contamination. The rural communities of Pampa del Zorro, Colonia Aborigen, El Jacarandá, Colonia Cacique, and Pampa del Indio were impoverished, isolated areas with low population density.

Rather than attempting to summarize project dynamics in each community, we share here some of the key actions that the working group deployed in the field to design and implement social technological systems.

ESTABLISHING AND TRAINING LOCAL AND NATIONAL TECHNICAL TEAMS

One project goal was to create interinstitutional technical teams at national, provincial, and local levels, which could then communicate with and support each other. To that end, we had two decision-making bodies: (1) a national coordination team with representatives from all public institutions involved and (2) a local team in each project area, with the involvement of local actors such as municipalities, schools, farmers' associations, health care centers, and associations of indigenous communities. In order to achieve a common language to guide the work, the Quilmes team designed a cycle of theoretical-practical training in the design and strategic planning of a social technological system. All officials and technicians involved in the project completed this training.

The training spaces provided a central location to discuss, from a sociotechnical perspective, the ways in which technicians and officials of the INTA, the National Institute of Industrial Technology (INTI), and local municipalities design strategies for rural intervention. The training course aimed to modify those linear and restricted perspectives that fail to go beyond a specific technology or issue and thus do not lead to systemic development strategies at a local level. For instance, INTA technicians are not always familiar with each rural property or the area as a whole. They had worked with groups of farmers and confined their attention to specific topics to facilitate focused research or extension of a specific area of knowledge. The training courses helped participants come to appreciate the complexity and diversity

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of development dynamics, including why an engineer also has to be an economist, a sociologist, or an anthropologist. It was not just a problem of deploying technological artifacts. It was a problem of constructing systems.

The critical analysis of linear or determinist thinking in conventional practices was rejected by some officials. We interpreted the difficulty as one of momentum in institutional and organizational cultures. Some teams of government officials who decided to discontinue their participation in the projects argued that there were no problems in the territories or that there was no need to improve methodologies of intervention. "The problem of poverty is a production and cultural issue. We have ways to address it. Why do we need another way of doing things?" said one government official. Time and time again, we found our work proposal and action plans to fall outside the rationales of existing public institutions. But we persisted. The Quilmes team developed a new set of social skills, especially learning to enroll and mobilize hierarchical actors. Most of the linear and determinist thinking was put aside when the political heads of the INTA and the National University of Quilmes asserted their authority on our behalf. Generated in the dynamics of learning by doing, these skills had to become routine parts of our work.

The Quilmes team initiated the training cycle and the research team made concrete the theoretical idea of social technological systems through their execution. At the same time, these organizational initiatives made it possible to establish creativity spaces more open to new mechanisms and work schemes and to redefine the scale of action on the basis of a broader view of territorial development. Also, the constant feedback from the national team generated new ideas for cofinancing the various proposals and for including new participants to help scale up the efforts.

LOCAL MANAGEMENT DESKS: A TECHNOLOGY FOR COMMUNITY ORGANIZATION

Another project goal was to democratize decision-making and control at local levels. To that end, it was necessary to create spaces for informed decision and dialogue that did not previously exist in rural communities with dispersed and isolated populations. The Quilmes team borrowed the idea of local management desks from the Ministry of Social Development, which had created such desks in urban areas and judged them to be a positive instrument for citizen participation (Ministry of Social Development 2013). The Quilmes team initially conceived the desks as a means for local actors—municipalities, rural consortiums, road consortiums, farmers' associations, school and health care officials, and community members—to come together to establish communication processes for planning and decision-making. However, for Quilmes team members, local desks raised a second-order question: What is our role in the desks? Do we control the desks, or are we participating as just one more actor? Could we introduce problems for a desk to add to its agenda, or must we step

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back and wait for a spontaneous decision to emerge? To us, the obvious answer lay somewhere in the middle. We had to learn to approach the situation with only a semicontrolled plan of action.

For villagers, the local desks became a way to reestablish a sense of community while including us, the Quilmes team, as part of that community. When we first began working, a local villager, Alicia, told us, "For years we have not seen our neighbors. We do not know what they do. . . . Since we have been working together, we have been able to recover the community. Now we work together, and we solve our problems together. We can dream of a better future for us."

In Pampa del Zorro, the first issue its desk confronted was to define its problem agenda. Participants in the desk included local families, teachers from the public school, professionals of the INTA, and us. The families lived several kilometers apart in a subsistence economy, and they immediately identified lack of access to public services, including water, sanitation, and health. The school had deteriorated significantly from a lack of funding. Neither the INTA nor any national public body had ever worked in that location. So we suggested using the desk to generate a decision-making mode for designing and implementing a local development plan.

In our ex ante diagnosis about the situation of rural communities in the north of Argentina we had identified lack of access to safe drinking water as a main cause of underdevelopment pathways. We introduced that diagnosis at the first meeting. Although desk members identified access to water as the main structural problem in Pampa del Zorro, the more important, most urgent and most difficult long-term problem was the bite of the "vinchuca."[7]

We had known about the problem of Chagas disease, but we did not understand the pain produced by the vinchuca bite. For us, this shared problem became an opportunity. It allowed us to think effectively about a common work agenda in which heterogeneous actors could address shared problems. But Chagas disease also posed a significant challenge. We didn't know anything about how to deal with vinchucas. We had no money to fumigate the houses, and we didn't know how to fold our initial water problem into the vinchuca problem.

Risking distraction from water, the local desk decided with our support to implement house fumigation against vinchucas as its first collective action. The fumigation was carried out by each local area, one house at a time. This decision required a collective commitment to purchase fumigation equipment, using local funds and funds from the university. Working together to solve the problem led to mutual recognition and built confidence. Five years later, this initial move to collective action had borne many fruits. Each family had its own water system, new houses had been built, and the school was fixed. The families had created a producer association, municipality officers had become part of the desk, and the INTA had established a permanent work zone in the area, where collective fumigation still takes place. This desk became the most successful in the water project.

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Each of the five local desks that were established defined its own core guidelines for commitments and joint work responsibilities, such as holding periodic meetings, making decisions on the local strategic plan, registering implementation monitoring and control, and maintaining means of communication. With the active participation of the Quilmes team, each desk developed social technological systems strategies in establishing parameters of design, redesign, and implementation.

STRATEGIC PLANNING OF SOCIAL TECHNOLOGICAL SYSTEMS

The core goal of the water project was to develop a new model for government intervention that would be capable of integrating local innovation dynamics to generate broad processes of sustainable and inclusive development. With that goal in mind, the water project team designed and adapted specific work methodologies and mechanisms aimed at operationalizing processes to achieve social technological systems. Some of these included the following:

- Instruments for population surveying and monitoring: One of the main problems in the design of inclusive development strategies is defining the target population. In Pampa del Zorro, for example, boundaries are fuzzy, which made finding the people difficult. We identified sixty-three families across an area of eight thousand square kilometers. In areas such as Colonia Cacique, much of the population is nomadic, and we worked with others to carry out a socio-habitational survey, a georeferencing of the population and water sources, and a photographic housing survey before launching the collective decision-making actions.
- Mechanisms for collective decision-making: Each community adopted its own model for decision-making. One chose raised-hand voting, another chose a lottery-like system, a third elected a representative, and two based their decision-making on ancestral criteria. In all cases, discussions were held as to what decisions implied in dynamic terms. Although the lottery[8] was the most impartial mechanism, it proved to be the least efficient and was later changed into a spatial planning-based decision-making mechanism. Under the lottery system, families built one water cistern in five days. With the new model, they constructed two water cisterns in three days. Each desk deployed its own criteria to balance inclusiveness, equality, and optimization of human and physical resources.
- Mechanisms for informed technological decisions and generation of sociotechnical capabilities: Building these capacities required (1) training the community in technological options, (2) practical training sessions for learning more about the technologies and assessing how they worked, and (3) collective reflection on the use, adaptation, and supplementation of technological systems (Juarez, Becerra, and Thomas 2018). Drawing on these experiences, the community of Pampa del Zorro deployed concrete water cisterns for each family, and the community of

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Colonia Aborigen deployed a huge collective cistern of fifty-two thousand liters made with locally manufactured bricks.

- Funding sources: A key problem is finding a continued flow of funding to build up the sociotechnical system, including access to water, health, production of good and services, education, sanitation, and housing. The Quilmes team worked with both the INTA and local communities to foster fund-raising skills.

Developed in an ad hoc way and adapted to each case, each instrument was oriented toward producing better-quality information, ensuring the collective and participatory nature of the process, and strengthening local capabilities for generating knowledge and innovation, mainly by stressing the analysis of technological options and the social adaptation of technological systems.

Operationalizing local strategies produced action in two steps, an urgent intervention followed by a structural intervention (DAPED 2014). Speedy resolution of access to water became a top priority in all cases, because access to water is a fundamental human right that should be guaranteed by the state. Early interventions purposely took place in public spaces, such as schools, community centers, and healthcare facilities, in order to demonstrate the associative and collaborative nature of the proposed process. Public action also made clear the importance of generating local technical capabilities, including theoretical-practical training in masonry, electricity, and water technologies.

Following that initial step, the structural intervention strategy was deployed. It included the design and implementation of systems oriented toward sustainable inclusive development at the levels of both the household and productive unit and the community.

In community terms, focusing on sociotechnical systems rather than artifacts alone generates dynamics at different levels. Among families, a new sense of engagement emerged with the territory and its institutions. "Now we can say to my son," said Alicia, "that here [in this rural area] he can make his future." And Cholo, the president of a local producer association, said, "We are very proud of our rural school. We worked together to provide water to the children." At the level of the municipality, public officials found new ways to work with isolated rural areas. A civil servant of Las Breñas Municipality told us, "After two years of working together, now we know how to use our limited budget to bring services to our rural population." In the official teams, INTA officials and Quilmes team members were able to generate new intervention models to scale up the scope of sociotechnical solutions.

BUILDING R&D CAPABILITIES BASED ON PROBLEMS IN THE FIELD

The construction of multiple community maps of the problem-solution relationship was aimed at deconstructing the monodimensional view of problems and putting forward systemic sociotechnical solutions. We discussed each problem and each solution with the community, and each community prioritized a unique agenda

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of topics (Matus 1988). Moreover, each community identified relationships among themes and technological systems in order to generate a systemic approach to solving the problems. Collaborative networks, based on problem-solution relationships, were created to promote new technological and institutional capabilities, as well as capabilities for interinstitutional articulation and coordination at the local level.

Working with partners, the Quilmes team developed a *methodology for informed decision-making and local sociotechnical adaptation*. This methodology comprises a pool of technologies (artifacts, processes, and organizations) preselected by the technical teams on the basis of the community's priorities and the relationship between locally established sociotechnical problems (Juarez et al. 2016). Communities receive theoretical and practical technological training and courses of action are established according to their collective assessment.

Technological options are linked to certain collaborative networks—that is, other institutions or people with techno-cognitive capabilities that are associated with the development and implementation of a certain specific technology or knowledge. These networks were important as a means to collaborate with the communities in the design of the sociotechnical systems, both when broadening the range of technological options and when thinking through possible complementarities among technologies. The communities organized and implemented a large share of the local interventions. This local emphasis reinforced decision-making and collective action, reaffirmed local technical capabilities, and enabled social learning not only about artifact technologies, but also about such organizational technologies as supply purchases, logistics, time allocation, and work team establishment.

The modalities used for intervention in the communities made it possible for some technicians from the INTA to rethink the ways they work in the field and begin looking for the capabilities needed for local strategies, beyond the capabilities available in each institutional unit. Thus, the techniques and methodologies became a source of instrumental support to overcome the linear problem-solution relationships that dominate current public policies and the approaches to technologies for inclusion that we had detected when reformulating the research agenda. Even these government officials began to develop new capabilities for systemic intervention. The various activities carried out under the water project have made it possible to enhance public policies and available technical knowledge beyond the project's territory.

Developing social technological systems means deploying "reapplication" dynamics—that is, avoiding practices of technology replication and the uncritical generalization of technologies. The idea is for learning generated in one place to be sociotechnically[9] adapted to others, in terms of both policies and technologies (RTS 2011). To this end, the water project established in one of its community projects a scale-up strategy that used the first community as a pivot. Using peasant-to-peasant methodologies (Holt-Giménez 2008), the local team created spaces for communities of learning with neighboring locales, inviting them to take part in

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the technological training processes. Some groups in Pampa del Zorro and Colonia Aborigen traveled to neighboring locales to convey their experiences in constructing local strategies. The theory behind this radial strategy involves gradually promoting the capabilities and resources needed to work in new rural areas, with the same water project technical team, and using the neighboring community's experience to generate emulation.

At the national level, the coordinating body for the project designed a research activity in all twenty-four Argentine provinces aimed at creating new inputs for policy decision-making around water, titled "Management of Scientific-Technological Lore and Knowledge for the Resolution of Water-Related Issues in Argentina: Survey, Systematization, and Analysis of Learning in Management, Technologies, and Regulations" (Juarez et al. 2016). The water project has also become part of the transnational SEDCERO program, a collaborative network of public and private organizations from Argentina, Bolivia, and Paraguay. The main goal of this program is to influence public policies to improve water and sanitation services and to develop integrated water management mechanisms for the region. With its commitment to social technological systems, the water project has produced learning that has informed local, national, and regional policies.

SOCIOTECHNICAL ALLIANCES IN THE WATER PROJECT

The water project's commitment to technology and social inclusion revealed a new set of problems related to how policy is made within government. Put bluntly, the policy process for designing, implementing, and evaluating projects was broken within both the S&T and Social Development Ministries. The link between the ministries is the research team, and thus the weakest element in the entire system is the concrete policy actor, the group of STS researchers. This situation represented a challenge for us in terms of integrating new learning strategies at the institutional level while working in the margins of the political system and in a very imbalanced power relation. At the same time, however, our identity as academics empowered us because policy makers saw us as neutral actors.

In both ministries, policies were designed from the top down; those affected by the policies had no role in their design. Design and implementation were carried out by different groups, and neither had officers to implement the policy decisions in other institutions, such as the INTA or nongovernmental organizations. Once again, we as researchers had to take the lead in implementing policies.

By taking the lead, we could examine the socioeconomic dynamics at the local level and implement our own strategy of field work. The Quilmes team designed a territorial intervention strategy, implemented it, and then learned from that experience in order to generate new instruments. In other words, the Quilmes team couldn't just give advice to the ministries on programs or instruments if we wanted the social

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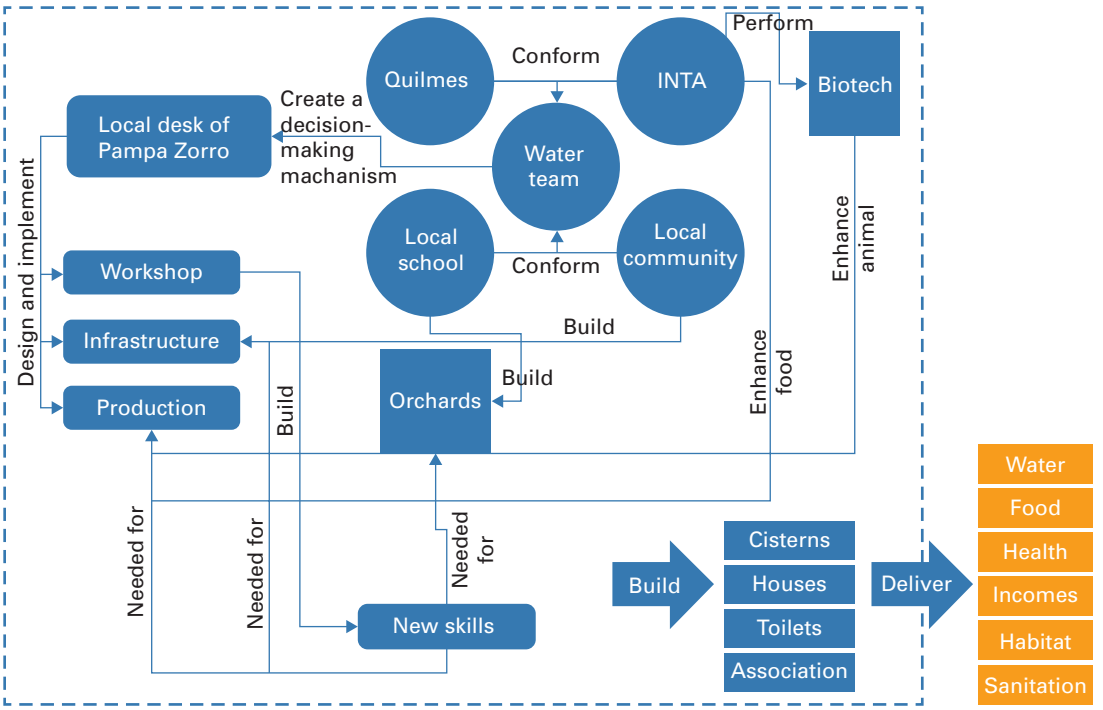
technological systems designed and deployed. According to that approach, "we" are the agents who deploy the policies in the field. "We" are policy designers and policy doers. "We" would be the learning unit. And "we" is in quotation marks because there was a social group behind the "we" that was bigger than the Quilmes team (INTA, municipalities, local communities, etc.).

Building sociotechnical alliances thus became an important step in constructing social technological systems oriented toward inclusive development. Consider, for example, the arrangement of sociotechnical alliances in Pampa del Zorro (figure 4.1). The water project team is integrated by different actors—the Quilmes team, INTA, local school, and local community—and implemented a local desk for decision-making. The desk deployed a range of actions. It carried our workshop for skill generation, including electricity, masonry, woodwork, and good practices of animal management. It built up infrastructure, especially water cisterns, toilets, improvements at the public school, and in houses. It generated new food production, particularly with organic orchards. The new system achieved important new dynamics. Each family has its own source of water. The whole community of Pampa del Zorro has a collective mechanism of small animal management. Families have toilets and showers. Kids in school receive better nutrition and improved sanitation. Houses are stronger. And most important, the residents have produced a community with its own mechanism of collective decision-making.



4.1 Sociotechnical alliances in Pampa del Zorro.

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RAISING THE STAKES: BACK TO THE STS FIELD

In this account, we show how the strategic decision to inflect public policies with the goal of fostering dynamics for sustainable inclusive development produced a trajectory of transformation for the research team. This trajectory included modifying the research agenda (from history of technology to a social problem setting), integrating policy design processes (during the work in the water project), and deploying technologies (especially new ways of organization) in the field.

Conceptual development was fueled by the new praxis, just as the praxis required leaving behind descriptive and analytic notions in favor of more planning-oriented concepts. In addition, these concepts revealed their usefulness for addressing a multiplicity of analytic objects. These included sectoral dynamics (durable goods, health, metalworking, aerospace, the pharmaceutical industry, nuclear power, and so on), scientific and technological policies, and research and development and innovation strategies (both at national and regional levels and at institutional ones). They also included new contributions to scholarly disciplines such as cultural anthropology, economics of technological change, history of S&T, sociology of technology, development policy, and S&T policy and management. At the same time, academic papers now constitute just a portion of the documents produced by the Quilmes team. Adding the roles of policy designer and policy doer to the research has led the Quilmes team to also produce policy documents (to inform public instruments), public communication of research outputs, training materials (for undergraduate and postgraduate courses) and, since 2017, an entire postgraduate university program, Planning and Design of Social Technological Systems.

Far from a practical agenda that competes with the academic one, the implementation of this research strategy generated new possibilities of development at the sociopolitical and socio-cognitive levels, both theoretically and empirically, as well as academically and politically, as two sides of the same coin: greater commitment and relevance on one side of the coin and higher quality and excellence on the other. Far from competing, the two sides were complementary.

Almost ten years after the beginning of this transformation, we can now say that this working group has reconfigured its idea of what research is. We now understand "research" as generating knowledge that is useful, collective, associative, and nonalienated for both public policies and organizations in the various territories. Research, for us, entails looking for a way to influence the political agenda when prioritizing thorny issues and when solving them. Research entails training decision makers in constructivist and sociotechnical planning methodologies. In addition, after ten years, the Institute of Science and Technology Studies of the National University of Quilmes—which was already a national and regional reference center for social studies of S&T—is now also a key institution in technologies for sustainable inclusive development. Over time, the research agenda and territorial action has become even

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more diverse and challenging, now including water, sanitation, and urban and rural development; circular economy, inclusive recycling, and social innovation; renewable energies and distributed generation; comanagement of national parks and empowerment of native communities; and evaluation systems of S&T institutions.

The work we did with communities, grassroots organizations, cooperatives, trade unions, policy makers, and even the academic community has generated knowledge commitments that have become irreversible. Designing is not about technologies for the poor but about strategies for the inclusion of all in possible and desirable futures. Or better yet, in possible new and desirable futures. And during the journey the critical analysis of the theory and continuing reflexive action over our own practices has been decisive at those times when we could not find answers to the problems before us.

Latin America still has many issues of underdevelopment, poverty, and violence. These problems will not be solved unless different social groups, including academia, become actively involved and set themselves to work in a coordinated fashion. And although established knowledge is a key tool, being willing to learn to solve new problems with others is central to the construction of solutions that are sociotechnically adequate for the territories. The field of science, technology, and society can play a prominent role in this learning scheme aimed at solving social and environmental issues. A critical view of scientific and technological dynamics is central to avoid ready-made, universal, and politically neutral solutions.

The challenge is thus put forward. The only thing left to do is raise the stakes.

ACKNOWLEDGMENTS

This chapter was made possible with the financial and institutional support of the National University of Quilmes (UNQ) and the National Scientific and Technological Research Council (CONICET). We wish to express our profound gratitude to our partners and friends at the National Institute of Agricultural Technology (INTA). The findings presented in the chapter are the result of our common work. Finally, we also want to give our special appreciation and thanks to Gary Downey and Teun Zuiderent-Jerak for their comments and reviews of the chapter and for the commitment involved in the production of this book. Any mistakes that remain are, of course, the sole responsibility of the authors.

NOTES

1. See the ministry's website at http://www.mincyt.gob.ar/estructura-ministerio (our translation).

2. The senior researcher was Hernán Thomas, a coauthor of this chapter, who in 2011 became director of the Institute of Science and Technology Studies at the National University of Quilmes.

3. One of those junior researchers with experience in appropriate technology was Paula Juarez, a coauthor of this chapter, who arrived at the institute following a previous journey as a social activist. Appropriate technology is small-scale, affordable, locally autonomous, and energy efficient.

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4. In 2010, Lucas Becerra, a coauthor of this chapter, started work with the Quilmes team.

5. For additional information, visit the RedTISA website at http://www.iesct.unq.edu.ar/index.php/en/redtisa.

6. Construction of the notion of social technological systems occurred simultaneously with the resetting of other analytic concepts used by the team—for example, the notions of "working/non-working" (Pinch and Bijker 1987), techno-economic networks (Callon 1992), and agency (Latour 1989). They were combined in a new concept, "sociotechnical alliance," This term refers to coalitions of heterogeneous elements that become part of the process of building the working or nonworking of a technology. Sociotechnical alliances are dynamic associations of alignment and coordination among artifacts, ideologies, regulations, forms of knowledge, social actors, economic resources, environmental conditions and materials, and so on. The constitution of sociotechnical alliances makes stabilization and assignation of meaning to certain technologies viable or unviable (Thomas 2012).

7. Locally, *triatoma infestans* (kissing bug) is called "vinchuca." It is a heteropter insect of the family *Reduviidae*, hematophagous, and one of the vectors that transmit Chagas disease. In Pampa del Zorro, the entire population suffers from Chagas disease.

8. The lottery system consisted of putting pieces of paper in a bag with the names of each family and then drawing out ten names at random. The order in which the names left the bag determined the order for allocating construction materials to each family.

9. In sociotechnical adaptation, technology production is a self-organized and interactive process that integrates a lore, artifact, or technological system in a sociotechnical dynamic or trajectory that is sociohistorically situated. This process integrates problem-solution relationships, working/nonworking, coconstruction dynamics, development of technological frameworks, reinterpretation of technologies, technological styles, and so on (Thomas 2008b).

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5

PARTICIPATORY DATA DESIGN

Acting in a Digital World

Torben Elgaard Jensen, Andreas Birkbak, Anders Koed Madsen, and Anders Kristian Munk

In a series of recent projects, the Techno-Anthropology Lab (TANTlab) and its collaborators have developed an approach to STS making & doing, which we now call *participatory data design* (PDD).[1] PDD projects are often organized as so-called data sprints, three- to five-day intensive workshops where STS researchers collaborate with stakeholders in a particular field to collect and generate data that is relevant to a particular problem—and together create a useful digital device or object (Munk, Meunier, and Venturini 2019). Thinking about such collaborations as a form of participatory design raises the question of whether and how PDD experiments can create more equitable and locally beneficial forms of data use by engaging local actors in the work of finding relevant data and of building something meaningful out of it. But the engagement of local actors also comes with a degree of unpredictability. In our experience, these kinds of participatory projects are different every time and often involve a feeling of loss of control and ambivalence about the role of digital data. This chapter therefore does not offer a finished conceptual framework but rather a demo in the shape of a number of stories about our projects, their recurrent features, and some of the dilemmas and tensions that arise when making and doing STS with PDD.

One of the central tensions that runs through the chapter is related to the contemporary imperative to do something digital in academia—and in society more generally. There is currently a strong interest in digital tools across the social sciences and humanities (Vertesi and Ribes 2019), which is something that TANTlab benefits from when generating institutional support and setting up collaborations with external partners. What is most interesting about the current imperative to go digital, however, is perhaps that it can be an opportunity to blur unhelpful dichotomies between qualitative and quantitative (big data) methods, between description and intervention, between online and offline, and between technical insiders and outsiders. The aim of this demo is to show how we try to work across such oppositions in

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our concrete makings and doings in TANTlab while also registering and attending to how these tensions constantly reappear in new disguises. Our aim is to ponder the consequences of having data as a boundary object between STS research and external stakeholders. Which role does data play in this context, and what kinds of procedures and goals can set the direction for a PDD process? In the following we give a short situation report from a particular moment in a recent project in which we and our collaborators found ourselves in the midst of the promises and difficulties of doing PDD.

John seemed to be out of his depth.[2] He had been arranging citizen hearings about new technologies for several years. He knew all about putting together the key information material for these hearings: a carefully worded leaflet given to the citizens with a balanced collection of expert views on a particular subject matter. He also knew that he was on solid ground institutionally speaking: his employer, the Danish Board of Technology, was an internationally recognized pioneer of technology assessment and citizen engagement. So basically, the task of organizing another citizen hearing on a technoscientific issue—in this case the dilemmas related to pandemics—should not cause too much commotion.

This time, however, the Danish Board of Technology had engaged with new odd bedfellows: a group of researchers from the TANTlab at Aalborg University who had promoted the idea that material gathered from social media such as Twitter could be used to identify the burning issues that should be brought before the citizen hearing. John and his colleagues from the board had quickly embraced the idea of doing something with Twitter data. They were well aware that more and more public debate takes place on social media platforms, and they were interested in ways to relate this new phenomenon to their existing methods, although also somewhat hesitant because of what they perceived as a lack of conventional methodological checks and balances in digital methods (Birkbak, Madsen, and Munk 2020). The group from the board and from TANTlab had met a few times before, and now they were engaging in a weeklong joint workshop to explore in earnest how large quantities of social media data might play into the work of the Danish Board of Technology.

When preparing a leaflet for a citizen hearing, it might seem a small step to take soundings in Twitter space rather than merely calling on established experts in the field. But as John and his colleagues soon realized, the new approach entailed more than just gathering information from a different source. In the normal process, John would hear or read every single word that the called-upon experts would deliver. In this case, the researchers from TANTlab turned up with a database of four hundred thousand tweets related to the Zika virus! With this massive amount of material, the process of identifying the issues had to rely on different tools and different types of choices. Rather than speaking to trusted experts and asking directly for their views on possible key themes, John and the other workshop participants had to navigate through a data-overwhelmed and thus rather disorienting situation.

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The digital tools provided by the TANTlab researchers allowed them to manipulate the large data set in various ways. The details of what was done on the computers of the TANT lab researchers was not entirely accessible or understandable to John and his colleagues. The outcome, however, was more tangible. At various points in time, the researchers printed out large, poster-size maps, displaying hundreds of words distributed in a number of hairball-like clusters, indicating that particular Twitter hashtags frequently occurred together in the material. Everybody gathered around these discursive maps, trying to make sense of the clusters. Whenever an interesting cluster was located on the map, the TANTlab researchers encouraged the participants to invent a tentative thematic label for the cluster and to read through some of the underlying tweets that had given rise to this particular constellation of words. The material would often appear excessive and with a lot of "noise" in the form of words that didn't suggest anything meaningful about pandemic-related issues. Repeatedly, the TANTlab researchers asked questions about how to filter the data: Would it be okay to look only at tweets with two or more hashtags? Would it be okay to look only at hashtag combinations with three or more distinct users? Such filtering decisions made it possible to print out new and potentially less "noisy" maps, which could then be examined.

The iterative process of visualizing, filtering, labeling, and collectively discussing went on for several days. It gradually became clear that the digital methods would not be replacing John's skills in identifying relevant topics for the citizen information leaflet. John's skills and intuitions just had to be incorporated in another way. At one point, the filtering process had returned a limited number of tweets that seemed to cover key aspects of the total material. At this time the workshop participants invented what they half-jokingly called the *John score*. Leaning on John's expertise, they asked John to read through the tweets and rate their relevance for the information leaflet. Did they point to a question or a dilemma that was important for the citizen hearing to address?

The tweets that were evaluated positively by John were incorporated into the information leaflet alongside the expert testimonies. In this way, a space and a role were created for new data opportunities within the normal operating procedures of the Danish Board of Technology. However, this space was not evident from the beginning. For instance, it was created by experimenting with different ways of moving between big data analyses of tweet patterns and close reading by John, who used his intuition as an expert in citizen engagement to make these analyses meaningful for the context in which they were to be used. Such experimental iterations are indicative of the emerging STS practice of PDD. In this chapter, we draw on our experience from several PDD projects and provide suggestions as to how STS researchers can work with external partners around data. We start by examining some of the developments that enable our current experiments with PDD. Then we delve into three key practices in PDD projects: datafication, flexible visualization,

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and materialization. Finally, we discuss some of the challenges and consequences of pursuing PDD as a particular kind of engagement experiment.

ENABLING CIRCUMSTANCES

Since 2015, we have experimented with the approach we now call PDD. In the following we describe some of the situated circumstances that enable and configure our work.

TECHNICAL DEVELOPMENTS ENABLING A DIGITAL STS

When the participants from the Danish Board of Technology were exploring the network of co-occurring Twitter hashtags about the Zika outbreak they were engaging in a practice that has now become commonplace but was difficult to imagine only fifteen years ago. It owes its existence to a convergence of digital developments that we can broadly label as digital methods (e.g., Birkbak and Munk 2017; Marres 2015; Rogers 2013).

The first of these developments is the emergence of social media, or what is sometimes known as the Web 2.0, which is characterized by a shift from static information sharing to dynamic, user-generated content on platforms like Twitter or Facebook (O'Reilly 2007). Social media platforms allow us to gather large amounts of structured data on how individual users interact with issues in real time (Lomborg and Bechmann 2014). In the case we described earlier, Twitter allowed us to download data on how users from all over the world were interacting with the hashtag #zika over a period of a month. It allowed us to track what questions they were raising in relation to Zika, which links they were sharing, what arguments they were pushing, and what other users they would typically associate with in doing so. Twitter has become one of the platforms through which a public can express its concerns around an issue, and this offers opportunities for research.

The second development is what we could call the popularization of computational methods for tracking and analyzing digital traces. It is of course possible to simply watch the Zika discussion unfold through the Twitter interface one tweet at a time. But the availability of tools like the Twitter Capture and Analysis Toolkit (Borra and Rieder 2014) for harvesting tweets systematically and the Gephi visual network analysis platform (Bastian, Heymann, and Jacomy 2009) has made it possible to easily conduct exploratory data analysis on large data sets (in this case almost half a million tweets).

METHODOLOGICAL DISCUSSIONS AND PROJECT PRACTICES IN STS AND MEDIA STUDIES

In the 2010s, academic fields such as media studies and (digital) STS have appropriated the new technical opportunities to study what Noortje Marres would call

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issue publics (Marres 2005) and what Bruno Latour would call controversies (Latour 2004). In close collaboration with software developers and data visualization experts, STS researchers have contributed to the further development and specialization of digital tools, and in conjunction with this, media and STS scholars have developed an increasingly sophisticated discussion about methodological challenges related to finding, harvesting, visualizing, and interpreting patterns of digital traces. These methodological discussions include reflection on how to think about the relationship between online and offline data (Munk 2013; Rogers 2009); how to bridge the qualitative-quantitative divide (Blok and Pedersen 2014; Munk 2019); how to take into account that each type of social media comes with a specific genre that conveys and configures particular types of messages (Burgess and Matamoros-Fernández 2016; Madsen 2013; Marres 2015); how to handle facts, values, and incommensurable positions in knowledge controversies (Birkbak 2013; Venturini 2010); and how to use data visualizations exploratively to pose new questions (Munk and Jensen 2014; Munk, Madsen, and Jacomy 2019; Venturini, Ricci, et al. 2015).

In parallel with the evolving methodological discussions mentioned earlier, STS scholars have learned some hard-won lessons about the difficulties of making data visualizations that are meaningful and useful to external parties. Early projects (e.g., MACOSPOL) were based on the implicit idea that sufficiently good visualizations would be picked up by the general public as easy-to-use tools for understanding and navigating public knowledge controversies such as discussions about vaccines or climate adaptations (Munk, Meunier, and Venturini 2019). Later projects (e.g., EMAPS) realized the necessity of inviting external stakeholders early and directly into the *engine room* when selecting and analyzing data (Venturini, Meunier, et al. 2015). For this reason, the data sprint format was developed where knowledgeable stakeholders (issue experts) were invited to give presentations of their views of the key challenges of their particular field and where the stakeholders were also involved in the subsequent data analysis and assessment of the data projects that were created through the workshops (Munk, Meunier, and Venturini 2019).

TAKING INSPIRATION FROM THE SCANDINAVIAN TRADITION OF PARTICIPATORY DESIGN

A final enabling circumstance that deserves specific mention is the tradition for user orientation and involvement in the fields of design and IT-development (Birkbak, Bornakke, and Papazu 2017; Callon, Lascoumes, and Barthe 2009; Munk, Meunier, and Venturini 2019), not least found in the Scandinavian tradition of participatory design.[3] Participatory design was originally developed in the 1980s in an effort by trade unions to gain influence on how workers' conditions were changed by the introduction of new production technologies, which the unions feared would lead to deskilling of jobs. The trade unions soon realized that resistance to new technologies

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tout court was an impossible strategy, but that valuable influence could be gained by attending to the many different ways that specific technologies could be configured. In principle, it would therefore be possible to negotiate a version of technology that improved rather than diminished the quality of work life. Today, we could raise the same issue in relation to the exponential rise of data and computational power: How can we negotiate a version of data practices that improves rather than diminishes life?

A second key lesson from the 1980s is the importance of the practical tools of collaboration. In the participatory design movement, it was quickly realized that the prospect of developing progressive technologies often hinged on intimate knowledge of previous work processes and conditions. Designers and implementers often lacked this knowledge, but under the right circumstances it could be brought to the table by workers, who could represent future users. This in turn raised methodological questions: What would be the best way of evoking the workers' sometimes tacit knowledge about work processes, and what would be the best way of staging the collaboration and negotiation between designers and future users? In the decades that followed, people in the participatory design movement worked on these methodological questions and developed a considerable repertoire of practical tools and approaches, such as future workshops, design games, mock-ups, and joint prototyping (Kensing and Blomberg 1998).

Our PDD projects are premised on the idea that the development of positive and meaningful uses of data will benefit substantially from direct involvement of the stakeholders, who are the potential future users. We thus share the collaborative strategy of the participatory design tradition as well as a keen interest in any kind of procedures and devices that can help articulate users' knowledge and open designers' decisions for negotiation. This raises questions such as whether the flexible visualizations that we discuss later could be considered a digitized version of the low-fidelity prototypes that characterize participatory design or whether the addition of data changes something more substantial in the participatory situation.

THREE KEY PRACTICES IN PDD

The varieties of enabling circumstances are parts of the background for the actual doing of the projects, which we turn to now. We draw on our experiences from five PDD projects carried out between 2015 and 2018.[4] But rather than describing every single project, we describe three key practices that were recurrent in our attempts to establish meaningful interactions between us and the participants in these projects: *datafication*, *flexible visualization*, and *materialization*.

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DATAFICATION

A PDD project is always about a particular problem: How can we use discussions on Twitter to improve the information material for a citizen hearing? How could Aalborg municipality gain sensitivity to public debates on Facebook while implementing a new school reform? How could the Royal Danish Theatre understand its visitors in new ways by looking at patterns of event attendance? When approaching these or other problems we do not simply import large quantities of digital data; we begin by actively engaging in *datafication*. Datafication is the process of gathering a substantial amount of digital data and relating it to a particular problem.[5] When we first meet with possible partners in a PDD project, we ask whether digital data might already exist that relates to the problem. We might ask also if people currently engage in activities that leave digital traces about the problem. Or we might ask if it is possible to actively get people to produce digital material.

The opportunities for gathering data are rapidly increasing as digital data and devices become more pervasive parts of social life, work life, political life, research, economic transactions, and all other sectors of society (Madsen 2015). In specific PDD projects, the datafication is a matter of seizing the opportunities at hand and finding the most relevant and accessible types of data. As a consequence, the types of data we have worked with are quite diverse. In a PDD project about obesity research we harvested a large number of scientific publications from scientific journal databases as well as a large number of food-related Instagram posts; in a project on school reform we and the municipality invited a vast crowd of stakeholders to participate in several months of debate on a specific Facebook page. In a third project, with the Royal Danish Theatre, we traced the activities of a large number of users across multiple Facebook pages.

Deciding on the relevant data source is the beginning of datafication. Other challenges soon follow. Digital data is usually abundant, which means that participants in PDD projects must decide to focus on a selection of the material, such as data generated within a particular time frame or by certain users. Another set of options that open up and need to be negotiated are questions about metadata and cascade effects. To explain this, it is useful to make a distinction between digitization and datafication (Mayer-Schönberger and Cukier 2013). As an example of digitization, we might think of a digital photograph of an old and fragile manuscript written on parchment. The viewer of the digital photograph can do no more or no less than a reader of the original document. The only thing gained is the ability to make cheap copies and to read without the risk of ruining the fragile original. Datafication, by contrast, is taking digitization an important step further. If, for instance, the photograph is scanned with optical character recognition technology and transformed into digital text, the reader will be able to perform a range of additional operations. She can do simple tasks such as a word count or identify the most frequent words in the document. She may also use her digital tools to make comparative analyses

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of the frequencies of words in different parts of the text or identity key phrases that often occur together. Or she may deploy digital tools based on machine learning to automatically detect the themes talked about in the text or the mood of its author. The possibility of performing all these operations indicates that datafication is quite different from simple digitization. Datafication allows us to deploy algorithms that add new layers of information (metadata) to the original material. Through this, it becomes possible to perform a cascade of operations that explores new combinations and correlations within the data set. In this way, datafication opens a series of data manipulation opportunities. A key activity of any PDD project is to discover and explore some of these opportunities and discuss if and how they may be of value to the stakeholders and the fields they are a part of.

The process of datafication often stimulates queries, which we might call ontological: What is really going on in this field, and what kinds of data might be relevant to relate to it? What are the essential parts of the phenomenon that we should attempt to articulate with or find in this data? Datafication also tends to stimulate discussions about the normative commitments of the participants: What kinds of analyses and visualizations could, or should, we attempt with this material? These are dilemmas that arise early in a PDD process, and even though they may generate tensions between the participants, these dilemmas make it necessary to be explicit about choices in ways that raise interesting discussions about the role of digital technology in society.

In several projects, we have seen that the value of datafication lies in stakeholders and issue experts discussing *at length* how to operationalize their concerns with respect to a specific data set. For instance, in the project with the Royal Danish Theatre there was an extensive discussion about the notion of authenticity. The participants had no doubt that authenticity was the hallmark of the royal theatre as opposed to other cultural enterprises, such as movie theaters. But when the participants were challenged to operationalize authenticity with respect to a large Facebook data set—when they had to datafy the problem—they found themselves in the midst of a thought-provoking discussion. Would it be possible to identify topics that were more authentic than others? Would ballet be a more authentic topic than football? Would an exclusive event be more authentic than a more popular event? Or was *authentic* a quality that users might indicate by using particular words? All these discussions brought the participants' knowledge and assumptions to the fore as they debated how to operationalize authenticity.

The lesson we draw from this is that PDD projects should avoid the temptation to define the key problems and concepts in advance. PDD should be approached as an opportunity to discuss and define the key problems with the issue experts and make a joint effort to operationalize these ideas in and with specific data sets. The practice of operationalization and datafication carries opportunities to "make our ideas clear" (Peirce 1955, 23). The cost of staying with the trouble in this way is that participants

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(including the organizers) will often experience a high level of uncertainty or even frustration because no one can guarantee that the PDD workshop will yield anything meaningful.

In sum, datafication is not a safe road to knowing everything about a field on the basis of massive amounts of data. Instead, datafication can be described as a riskier path that allows the participants to explore difficult ontological and normative questions and to open up possibilities for further development of data. We see this as a mode of pragmatic inquiry that involves redefining problems through empirical experiments (Munk, Madsen, and Jacomy 2019).

FLEXIBLE VISUALIZATION

The second key practice in PDD, closely related to datafication, is the extensive use of flexible visualization. If a visitor dropped in on an ongoing PDD project, he would immediately encounter a number of data visualizations. On the walls he would most likely see pie charts, timelines, and large, poster-size prints of network maps showing hundreds of words connected by lines of various lengths and thicknesses. The network maps would be littered with comments on post-it notes, or the project participants may have written directly on the maps, adding comments, drawing arrows, or circling portions of the map. The visitor might also witness people gathering around laptops or larger screens more convenient for group discussions. Most of the time the screens would show steady images similar to the printed maps, but occasionally the participants would start some kind of operation that would cause the networks on the screen to slowly start moving as if the whole network was being pulled apart while some parts of it were still hanging together. Seconds later, the participants might stop the movement, study the new configuration carefully, and perhaps add color, zoom in, or in some other way manipulate the display. Occasionally, the participant would switch to an entirely conventional mode of data display: a spreadsheet with rows and columns.

There are two main reasons for data visualization's enthusiastic use by PDD projects. First, that visualizations under certain circumstances may have the power to be very *persuasive* and force participants to relate their discussions to a shared visual object. Second, that data visualization may open new opportunities for *participatory design*. Let us discuss the two reasons in turn.

The persuasiveness of visualizations has been a significant empirical topic in STS. Anthropologists and historians of science have investigated how natural scientists have developed the craft of producing images and of putting large amounts of information into condensed formats (Coopmans et al. 2014; Lynch and Woolgar 1990). Latour (1990) argues that visualization not only sorts and organizes material in a way that allows scientists to get beyond a data-overwhelmed situation; it also creates the powerful effect of equipping actors with objects, which they can mobilize

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as allies in discussions with others who disagree. Accordingly, Latour describes the development of the sciences, their increasing persuasiveness and sophistication, as part and parcel of the invention of imaging and visualization techniques. To visualize, in the sciences, is thus not merely to illustrate something, which might just as well be represented in another format. To visualize is to draw things together in a way that produces clarity, strength, and persuasiveness. A pie chart showing the distribution of a national budget or a curve showing the correlation between smoking and cancer tends to be far more persuasive than anecdotes about the state of an economy or health risks. The persuasiveness of visualizations within science is to some degree the power or the magic that PDD projects tap into when they produce data visualizations. We can all be skeptical or simply refuse to believe specific studies or scientists. But we also all live in a world where the entire *genre* of scientific facts is heavily associated with graphs, maps, pie charts, tables, and the like. So when PDD projects deploy data visualizations, we are tapping into a well-established scientific genre that is generally known for its persuasiveness. More importantly, this persuasiveness serves a specific function as a boundary object among the participants in the PDD process. When participants have collectively agreed on an operationalization (of, e.g., authenticity) they are likely to take an interest in and try to relate to the visual outcome of that operationalization.

But persuasiveness of visualizations is not a controlled and predictable effect. On certain occasions we have found that data visualizations are almost more persuasive than we might want. Anders Munk found, for instance, that when he taught a project management course for engineers, he got far more attention from the listeners if he displayed a moving data visualization on a screen behind him. On other occasions we have discovered that the collective trust in particular types of visualization that STS scholars have described in branches of natural science is not necessarily present in the group assembled in a PDD project. The network graph, which is our most frequently used mode of data visualization, is challenging for many participants. Most people have strong visual literacy with respect to well-known forms of data display, such as a line graph or a pie chart. But these skills cannot be transferred to a network graph, which does not depict a correlation or a distribution but rather an elaborate set of relations between a large number of entities. Counterintuitively, the location of a cluster (up or down, left or right) does not carry any specific meaning on a network graph of the type shown in figure 5.1,[6] and neither does the specific location of the entities within a cluster. What does carry meaning is the number of clusters, their density, and the extent of connection between them. A part of our role when arranging a PDD project is to explain new formats of visualization and to guard against overinterpretation. This might be challenging when participants are eager to impute their previous knowledge of the project's field onto the maps—for instance, by quickly and directly associating the entities they know from the field with specific clusters on the maps.

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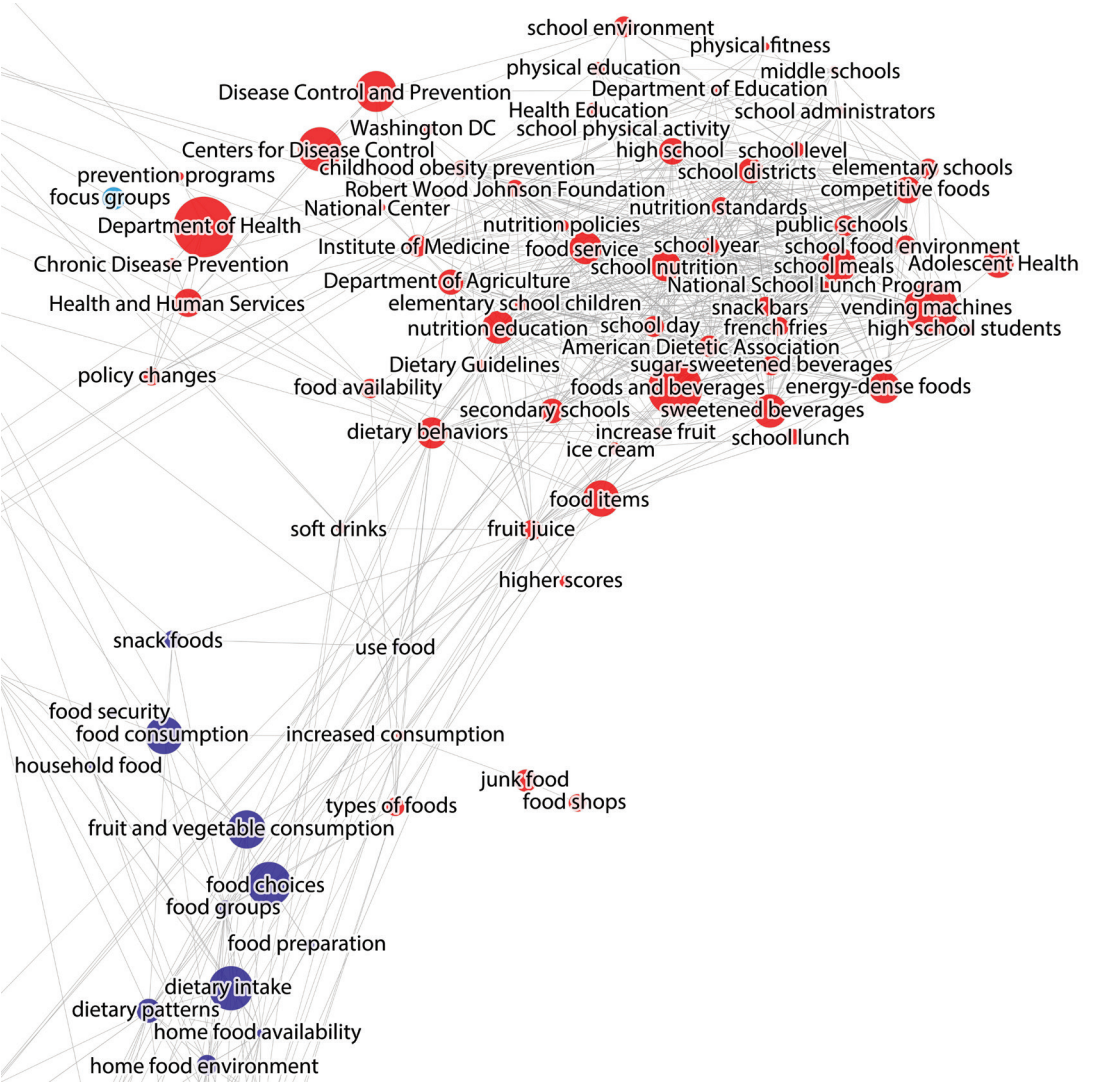

5.1 A network visualization of key phrases in obesity research literature (excerpt from a larger visualization in Elgaard Jensen et al. 2018).

The possibility of establishing persuasiveness—despite the unpredictability just mentioned—is one benefit of visualization. The other benefit is the opportunity to arrange a *participatory* process. Participation springs from the *flexibility* of contemporary data visualizations. In contrast to more static images, data visualizations can be generated quickly, displayed and enhanced in various ways, and reworked swiftly. In a PDD project, visualization can do some of the same work that cheap, pliable materials such as cardboard boxes and Lego brick models did in the Scandinavian tradition of participatory design. The key to bringing designers and workers together was to use flexible, low-fidelity materials that made it possible to play around with

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different future work situations and to bring both workers' and designers' knowledge into an open collective process. A crucial element of the collective learning in these projects was the quick feedback between exploring options, such as a particular arrangement of people and machines in a workflow, and the consequences of that arrangement, such as the possibility of assisting each other in the case of breakdowns in the workflow (Ehn and Kyng 1992).

What we try to achieve in PDD projects is similar. By rendering data in an accessible visual format, we put objects on the table, the wall, or the screen, which the stakeholders can immediately relate to their knowledge of the field: Does this make sense or not? Will this use of data be important and valuable to the field or not? Returning to our opening example, John and the other participants certainly asked themselves such questions when they were confronted with the discursive maps of Zika themes and decided to make filtering choices in their search for clusters of tweets that could be relevant to a citizen hearing on pandemics. Ultimately, the result of these choices was a series of new visualizations that gradually shaped the questions that the PDD project set out to answer.

We have come to encourage the quick development of alternative visualizations as a vehicle for creating learning situations that bring STS researchers together with knowledgeable actors from the fields we are exploring. Yet despite all the advances in computational speed and data handling, we have difficulties achieving the kind of participation that people might experience if they stand around a Lego brick model of their future office area and debate where to place the walls. In this scenario anyone can reach out and move a Lego brick wall and anyone can quickly respond to this future scenario. In a PDD project the flow of events is often more restrained: An issue expert might suggest a particular way to cut the data—for instance, by delimiting the view to a shorter time period or by filtering out the actors who are relatively unconnected to other actors. If the group decides that this would be an avenue to pursue, one of us would have to do some work to create the next data visualization. This may be a matter of minutes or hours, and it may require leaving the room to produce a new printout. For this reason we have found ourselves on the constant lookout for technical developments that enable even quicker iterations of data viewing.

MATERIALIZATION

The work with datafication and flexible visualizations makes it possible to build tangible outcomes whose equivalents did not exist before. Here are three brief examples: In a project on the topic of obesity research, the outcome was a prototype of an analysis showing a surprisingly fragmented discursive landscape in a large collection of journal articles (Elgaard Jensen et al. 2018). In a project with the Royal Danish Theatre, the outcome was a map showing how the active users of the theatre's Facebook page were also active on other culture-related Facebook pages (Munk, Madsen,

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and Jacomy 2019). The map gave the theatre an image of what competed for its audience's attention. Finally, in a project on implementing a school reform in the municipality of Aalborg, one of the outcomes was an online resource (a database interface) that made it possible to search and visualize the connections between more than nine hundred specific visions for the future school (Madsen and Munk 2019). These visions were formulated at a large meeting by teachers, parents, administrators, politicians, and others, and the material remained available as a reference point for the ongoing discussions about school policy in the municipality.

As our three examples indicate, the outcomes of PDD projects may be quite different—depending on the participants' interests and the availability of data, time, and resources. Despite the differences, two general points can be made. The first is similar to the argument about flexible visualization: If the strength of PDD projects is that they bring different kinds of people together, then it is crucial to create situations in which their knowledge can meet and be negotiated. Looking at and modifying a data visualization together is one such occasion. The goal of producing material outcomes toward the end of a project is another way to propel participants to create something, which can be an object of negotiation and collaboration. Once a final visualization, a prototype of an analysis, or a user interface is on the table, the stakeholders can comment on whether this object would make sense to other actors in their field and, if not, how it might be improved. A material outcome here becomes a device for articulating the participating stakeholders' knowledge.

The goal of material outcomes raises a tension concerning the kind of democratic ideals that shape these outcomes. The tension can be described with reference to what John Law (2009) calls "constitutionalism" and "interference" (see also Munk and Abrahamsson 2012). Is our task to create a situation that is sufficiently messy to resist any attempt to subsume it under a singular ontology (interference)? Or is our task rather to account for the multiple positions from which we will eventually have to craft a common world (constitutionalism)? The answer varies from project to project. For instance, the prolonged collaboration with the municipality of Aalborg was premised on crafting a visualization of the public debate that was deemed legitimate across people with different opinions, whereas the sprint with the Royal Danish Theatre had a more experimental premise and was meant to disturb preconceived notions of the cultural audience.

Our second point about PDD outcomes relates to the reception beyond the direct participants. We have limited opportunities to trace the long-term fates of the prototypes we produce. But occasionally we do get the chance to witness how organizations use the results of PDD workshops. One such occasion arose when John—the person from our opening story—invited some of us to be present at the Danish Board of Technology's citizen hearing on pandemics. As always, the citizens were given an information leaflet but this time one that contained the materials (selected tweets) that had been identified at the PDD workshop. It was gratifying for us to see the

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material printed in the leaflet. As far as we know, it was the first time that the board had solicited sources other than established experts. However, when sifting through the leaflet, we also realized that the usual amount of expert testimony was still in the leaflet, and it greatly outweighed the small handful of selected tweets. As the citizen hearing unfolded, we also realized that the board had organized the deliberative process with the invited citizens in exactly the same way as before and that the tweets were scarcely mentioned in the discussions.

In an almost ironic way, the tweets in the leaflet symbolize both the hope and the difficulties of PDD. It is no small thing to have facilitated the adoption of a new type of information source into the machinery of the Danish Board of Technology, and we don't think we could have done it if we had not involved John and other stakeholders in producing a material outcome with key intuitions of the board built into it. But it is also clear that anything we produce in a PDD workshop is at the mercy of many indirectly involved stakeholders and obdurate organizational practices. In the discussion that follows, we offer some further reflections on what this long run might entail.

DISCUSSION

So far we have discussed the enabling circumstances of PDD projects as well as some of the key practices in these projects. The practices suggest some of the visions that guide us, including our intention of making the most of the new opportunities for datafication, our ambition of working collaboratively with stakeholders, and our aim of establishing learning situations using flexible visualization of data. We believe it is fair to say that these visions have been fulfilled in some measure. We have indeed collaborated and learned together with stakeholders and we have made new things with large amounts of data. However, we have also encountered different effects—intended as well as unintended—that require further discussion.

The first is a surprising sense of empowerment as STS researchers, because our knowledge products seem to travel in new ways (see the introduction to this volume). Compared with the usual products of STS scholarship—articles and books—the digital products are often engaged with much more by different actors. This has launched us into the position of being the ones who can deliver visually appealing objects that attract a good deal of attention. Even more strikingly, we have experienced that collaborators are willing to grant power to digital maps—for instance, by describing the maps as the actual, data-based facts, as opposed to their own previous representations of the field, which the stakeholders begin to describe as being more loose, sense based, and incomplete. Finding ourselves in this situation as STS researchers is a highly ambivalent experience given our research tradition's long association with constructivism. It is clear, as Downey and Zuiderent-Jerak note in the introduction, that both "the scholar and the scholarship get made and done in the

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process." Although we welcome the passionate engagement with the visualizations, we try to stress their constructed nature, the uncertainty of data, and the dangers of reading too much into them (Munk, Madsen, and Jacomy 2019).

A second effect, which almost runs counter to the first, is a sense of loss of control. Working with PDD projects means seeking out stakeholders and issue experts, which again means that STS researchers cannot occupy the role as the knowledge authority in the field in question. The stakeholders have a considerable say in framing the project and its outcome, and in the aftermath we have often seen that digital maps or devices have been carried away by the stakeholders and incorporated into arguments and decisions that would normally be beyond our reach. In a sense, our loss of control over the outcomes of the PDD projects is a success, because it fits the intention to engage stakeholders and produce something of use to their practices. However, it also means that we need to rethink not only our ideas of authorship and ownership of our knowledge products but also what sort of situated ethical responsibilities we have when these products are carried away by external partners.

Although appearing opposed, these two effects—the gain and the loss of control—also interact. When participants assign the quality of facts to PDD results, we as researchers are sometimes simultaneously disempowered and more likely to lose control, because the products travel much faster to other settings when wrapped up as facts. One example of this appeared in the school reform project with Aalborg municipality, which in addition to an interactive database of Facebook comments and posts, also produced a more static network visualization of the main themes and their association. The visualization suggested that not all teachers were united in their critique of the school reform, which politicians and municipal leaders could use to destabilize the opposition they were facing from the teachers' union. In this case, we as PDD researchers became very attractive collaborators for those already in a powerful position, something that empowers and betrays at the same time, because we appreciated the attention but did not necessarily agree with being mobilized as evidence against the teachers.

A third effect of PDD, which can be used to work against such dynamics, is the particular problematizing or even deconstructive effect that may be achieved through data work. We could use this as a slogan and say that the aim should be to *slow down reasoning by speeding up data*. Quick assumptions about, say, the unity of the field of obesity research or the typical views of parents on school reform may be challenged if one can collect and explore a large data set on the issue. But quick assumptions may also be challenged simply by *trying* to collect data, such as in the case of the Royal Danish Theatre participants who had to slow down and define authenticity before they could even begin looking for relevant data. The effect of slowing down reasoning[7] is in our opinion the feature that most strongly indicates how PDD is not a consultancy gig on the side but a mode of doing STS work (see the introduction). STS has a long tradition of working against received notions, of articulating multiplicity, and

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of showing how things could be otherwise by attending to historical or ethnographic details. We think PDD projects—equipped with digital resources and in collaboration with stakeholders—instigate a similar kind of ontological inquiry that works against universalistic and too-quick assumptions about the world.

A fourth and final implication relates to our role as STS researchers, in particular our often self-appointed role as the ones who make multiplicity visible. When engaging in PDD projects together with actors who are profoundly involved in a particular issue, it becomes clear that the benefit of multiplicity is always a situated and contested matter. The kind of multiplicity wished for by one set of actors may run counter to the interests of others. In one striking example, we saw how a municipality's wish for a wide and broad debate about school futures effectively sabotaged the teacher union's attempt to defend the interests of its members by speaking in unison. Faced with cases like this, it seems that PDD projects not only empower STS and engage us with new and interesting collaborators; PDD projects are occasions for reflexive STS learning (see the introduction) and for reexamining core values of STS, such as the field's long-lasting devotion to multiplicity. In particular, PDD projects suggest that as we enter contested fields, we constantly encounter stakeholders who have a strategic interest in producing particular kinds of multiplicity.

This does not mean that we will simply become merchants of multiplicity hired by particular stakeholders to help them perform a targeted deconstruction operation. Datafication processes, such as those described earlier, can reopen entrenched normative commitments, both for researchers and for other participants who are faced with the very practical challenge of operationalizing goals and ideals. One way to stay in such troublesome moments is to make the data sets produced in PDD projects as widely available as possible rather than just publishing results and circulating selected visualizations that support particular points of view. In the Aalborg school project, for instance, we insisted that all the formulated visions should remain publicly accessible online. A related option is to prioritize visualizations that are interactive in ways that keep the analysis open for reorientation—for instance, by allowing future users to choose between alternative criteria for inclusion and different metrics for ranking data. Circulating data sets and making interactive visualizations open-ended harnesses the potential for slowing down reasoning that the multivalence of digital data offers and extends the making and doing of PDD to settings other than the initial one. Indeed, part of the trick of datafication is to realize that other situations and settings have already shaped what can be constructed as data, and in this spirit, it makes sense to anticipate more such situations after a specific PDD project comes to an end. One of the key tasks for developing PDD further is, then, to find ways to facilitate the ongoing making and doing of PDD. Ultimately, our ambition with the PDD projects is not just wrapping up projects with neat material outcomes but setting in motion processes that collectively engage more actors with datafication as a means for ontological inquiry and building new things.

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ACKNOWLEDGMENTS

Our notion of participatory data design has evolved through extended dialogue and collaboration with a large number of fellow academics, students, and external partners—far too many, unfortunately, to mention and thank individually. We are profoundly grateful for the energy, resistance, and creativity that they have all contributed.

NOTES

1. The term was first used in a Danish book chapter (see Elgaard Jensen et al. 2017).

2. The following account is based on Anders Koed Madsen, Anders Kristian Munk, and Andreas Birkbak's experiences as participants in a project with the Danish Board of Technology. For a more detailed account of the project, see Birkbak, Madsen, and Munk (2020).

3. For reviews of the participatory design tradition, see Asaro (2000), Kensing and Blomberg (1998), and Törpel et al. (2009).

4. The five projects we refer to here are the following: obesity research (Elgaard Jensen et al. 2018; Munk et al. 2016), ASSET (Birkbak, Madsen, and Munk 2020), Aalborg school reform (Madsen and Munk 2019), the Royal Danish Theatre (Munk, Madsen, and Jacomy 2019), and fake news (Bach et al. 2018; Bounegru et al. 2017). Our thinking about PDD has also developed in dialogue with colleagues doing similar kinds of work, in particular Morten Misfeldt and collaborators' work on datafication of learning goals in Danish primary schools (Misfeldt et al. 2018). Digital methods development and reflections have also evolved through projects in which external stakeholders were not firsthand participants (Birkbak, Bornakke, and Papazu 2017). The PDD approach builds on broader efforts to involve stakeholders in digital STS, in particular the so-called data-sprint approach (Munk, Meunier, and Venturini 2019; Venturini et al. 2014, 2015).

5. Some authors consider datafication to be an inherently negative tendency in contemporary society. We use "datafication" as a neutral word indicating simply the process of gathering and relating data to a specific problem. Whether datafication is beneficial or harmful is an empirical question. For approaches similar to ours, see Flyverbom and Madsen (2015) and Schäfer and Van Es (2017).

6. The network graph in figure 5.1 is spatialized with a force-vector layout (Jacomy et al. 2014).

7. See also Whatmore (2009) and the way she draws on the Belgian philosopher of science Isabelle Stengers.

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6

DOING ETHICS WITH COD

Max Liboiron, Emily Simmonds, Edward Allen, Emily Wells, Jessica Melvin, Alex Zahara, Charles Mather, and All Our Teachers

I'm the guest of my friend and two men I've just met from Nain, the most northern settled town in Labrador, Canada. It's my first time fishing for Arctic char. I'm excited. I'm here because I'm a scientist and I need fish guts, plus I love fishing. But when I look around the boat, there is no fish bonker—that wooden stick you use to bonk the fish over the head. Uh-oh. How do you kill the fish? I throw out my line carefully, so that I don't catch anyone. The men are catching char after char, throwing them over their shoulders into the fish boxes and casting out again without looking back. The fish suffocate. When my friend catches her first fish I ask if I can kill it. She nods. I grip the fish between my knees and I cut its throat, sawing and sawing away. My borrowed knife is dull. The skin is unexpectedly thick. Shit, shit, shit. I'm doing a bad job. The char is bleeding and bleeding but is still alive. I cut deeper and deeper, past its gills. Still alive. Shit. Past its eyeballs. Its head is nearly off. Still alive. I am covered in blood and black flies. I throw the char in the fish bucket, where it bleeds out. Shit. The next time my friend catches a fish I cut deeper and faster. Still not good. She lands a third fish. I feel sick. I am going to have to keep sawing away like a shitty idiot. The boat driver interrupts his casting to pick the fish out of my hands by its tail and whack its head against the side of the boat. Dead. Thank god. I start catching fish and whacking them. Though only mine and my friend's. Turns out, you don't slit a char's throat. You have to whack char. I really need to add that to the lab protocol (figure 6.1).

We are members of Civic Laboratory for Environmental Action Research (CLEAR), a feminist, anticolonial marine science laboratory. Through our handling of fish, dull knives, specimen bags, and intestines, we find that we must be accountable to these things and their worlds in ways that don't always show themselves when we are theorizing at our desks. Indeed, understanding accountability in practice is a core strength of making & doing as a methodology in STS as "a mode of scholarship that involves attending not only to what the scholar makes and does but also to how the scholar and the scholarship get made and done in the process" (Downey and Zuiderent-Jerak 2017, 225). Intervening in material processes in the world as feminist and anticolonial scientists means that we engender specific relations and thus specific obligations.

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6.1 Arctic char caught in Nain, Canada, 2016.

These obligations come from where we are from, including our Métis, Kablunangajuk, local settler, and come-from-away settler positions. These obligations also come from our research, both as scientists and as STS scholars, as feminists and as anticolonialists. Yet as you may have anticipated, these obligations are sometimes at odds with one another. Thus, our obligations and relations are often compromised, meaning we are beholden to some over others, and reproduce problematic parts of dominant frameworks while reproducing good relations at other scales. Compromise is not a mistake or a failure—it is the condition for action in a diverse field of relations (Fortun 2009 is a key STS text that articulates and grapples with this concept). To imagine otherwise is to subscribe to "*Terra nullius*, the coloniser's dream," which, Raweyn Connell writes, "is a sinister presupposition for social science. It is invoked every time we try to theorise the formation of social institutions and systems from scratch, in a blank space. Whenever we see the words 'building block' in a treatise of social theory, we should be asking who used to occupy the land" (2007, 46). CLEAR's field of action is not a blank slate. We understand that any act of resistance is "partly implicated in the very systems of oppression they set out to oppose" (Man 2006, 98), inadvertently reproducing parts of the system while challenging or changing others. This compromised, emplaced terrain is where we make and do relations and where we struggle to do them well according to the values of equity, relationality, humility, and reciprocity outlined in feminist, anticolonial, and Indigenous thought. These ethics—efforts to mind our relations in a compromised field—are difficult, imperative, and the topic of this chapter.

There was a specific way that people in that boat in Nain were catching and killing char, and those methods came from their relations. The lab member's (strained,

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evolving) methods to kill fish by slitting throats and whacking heads came from her obligations to her father, who taught her to catch and kill fish quickly; to her Elder, who taught her about good relations in general (including keeping a sharp knife); to her friend on the boat, who invited her to her home in Nain; to the men on the boat, who invited her onto the boat; and to the fish, who died. She killed her and her friend's fish, but not the men's. That was *not* her place. One of the men, accountable to his guest, showed her how to bonk the fish on the boat. The men had other obligations, too, that made them throw the char in the box as fast as they could—they had to fill freezers (theirs and other people's) in a place with acute food insecurity. Perhaps. Our lab member was a guest, so this is her speculation. The point is that different relations make different obligations, which engender different methods. This is not relativism but is a deep specificity based in place and the relations to which we are accountable.

STS concepts such as assemblages, materiality, vibrant matter, interspecies, and agency are all fundamentally relational, articulations of "understanding[s] of relatedness" (Mol 2010, 257), in which two or more beings (humans and otherwise) are inextricable from one another's influence, action, and world making. These concepts help us operate "against the implied fantasy of a masterful, separate actor, [because] what is highlighted is the activity of all the associated actors involved" (Mol 2010, 256). Feminist STS scholars such as Helen Verran (2001), Michelle Murphy (2015), Karen Barad (2007), Donna Haraway (e.g., 2013), Lucy Suchman (e.g., 2002), and Astrid Schrader (2010), among many others, extend STS concepts of relationality to argue for response-ability and accountability in these nonmasterful, enmeshed relations. In a different but sometimes overlapping intellectual tradition, Indigenous thinkers argue that "relationality is . . . an ethical stance that requires attentiveness to the responsibilities that come with a declaration of being in relation" (Donald 2012, 535). Both feminist STS and Indigenous thought agree that things are *constituted* by these relations rather than preexist them. In Indigenous thought, obligation is a key way to describe that constitution. We follow these threads of feminist STS and Indigenous thought to understand that relations, ethics, and obligation are synonymous, and we aim to enact that understanding while making & doing marine pollution science.

CLEAR's efforts to attend to our obligations are worked out and formalized in protocols. When we say protocol, we call on its meaning in both science and ceremony to mean "the manner in which one approaches each and every element in our space" as a manifestation of our values and goals (Keali'ikanaka'oleohaililani 2014, 77). In a scientific laboratory, protocols are the scripts you follow to keep your controls controlled, your science replicable, and your findings valid. Step 1: tie back your hair and put on gloves. Step 2: rinse the sieve three times. Step 3: rinse the outside of the specimen bag in water before placing it in the sieve. In all these actions, you're looking out for contaminants that might creep into your sample. Protocol also refers to guidelines for conduct during ceremony: bring the hosting Elder tobacco (loose

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cigarette tobacco will do, but leaf tobacco is better) in a red cloth bundle; present it in your left hand, and let the paarantii kaayash ooshchi take it from you. Don't put it in their hands—it's a gift and it must be accepted. In both science and ceremony, protocols reinforce and perpetuate what is meaningful and right in an activity (Whyte, Brewer, and Johnson 2016; Tallbear 2014). They are enactments of our values and guiding principles, and they instruct us in how to reproduce what is good. Sometimes they are prescriptive, and sometimes they are about the maintenance of everyday life and well-being, but they always point you in a good direction and serve as an orientation. Our orientations that we inscribe in our protocols are the values and theories articulated in feminist, Indigenous, and anticolonial movements and thought (key among them are Ahmed 2017; Arvin, Tuck, and Morrill 2013; Chavolla 2007–future; Kimmerer 2013; Grande 2015; Murphy all years–future; O'Brien 1993; Todd all years–future; Tuck and McKenzie 2015; Tuck and Yang 2012; Smith 1999; and Wilson 2008).

As many STS researchers have shown, scientific research cultures reward individualism (Ross 1992; Man 1999), heroism and machismo (Carey et al. 2016), and frontierism (Tilley 2011), in addition to consistently privileging white, male bodies and knowledges (Murphy 2006). Like most other forms of academic research, science assumes access to land as a resource for knowledge, a core impulse of colonialism (Coulthard 2014, 7). CLEAR is committed to Western science and its ways of knowing—we are marine scientists!—but we are not committed to all values that undergird and reproduce the dominance of science over other forms of knowledge and many of its practices and assumptions, including entitlement to land. It makes for an uneven terrain.

CLEAR does research on marine plastic pollution, particularly those plastics ingested by animals caught for food by rural and Indigenous peoples (e.g., Liboiron et al. 2016). In the province of Newfoundland and Labrador, Canada, this means we work mainly with Atlantic cod, as well as Silver hake and Arctic char (including that char from the introductory story). We are aligned with other fish-oriented people who understand how "human-fish relationships represent a whole host of social, cultural, and legal-governance principles that underpin life" (Todd 2014, 218; Todd 2016, 2017, 2018; Price 2007; Hoover 2017; Fox et al. 2017). This chapter follows fish into our laboratory, where their gastrointestinal contents are turned into data and then brought back into the world as scientific research. We choose key moments when practices matter in terms of navigating accountability and good relations. These moments are told as storied memories by various lab members. Here, as elsewhere, research is not inherently good (Murphy 2006; Deloria 1969; Smith 1999) even when it is trying very hard to be good. Creating and testing feminist and anticolonial research methodologies in science that foreground good (accountable, obliged) relations is the main goal of CLEAR. These are our stories of staying with that trouble.

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LESSON ONE: RELATIONS ARE COMPROMISED (COLLECTING SAMPLES)

Scientists have argued that the vast majority of marine plastics—93%—are smaller than a grain of rice (Man et al. 2014). This means many animals, from whales to plankton, can ingest them. For the authors, as for many marine scientists, the problem with animals ingesting plastics is not that they might choke or otherwise be harmed by the plastic polymers, although we've seen this happen occasionally (Rochman et al. 2016). The problem is that plastics absorb hydrophobic (oily) chemicals (Rochman et al. 2013a). You've seen this if you've ever stored chili or curry in a plastic container and then can't scrub the orange color out of the plastic—the plastic has absorbed the oily tomato sauce. In the ocean, there is less tomato sauce and more industrial chemicals such as flame retardants (like PCBs), pesticides (like DDT), and heavy metals (like methyl mercury), all of which scientists have found concentrated on marine plastics up to one million (10^6) times more than the surrounding water (Teuten et al. 2007). When animals ingest plastics, these chemicals can move from the plastics into the animal's tissues (Rochman et al. 2013b, 2014), where they can accumulate and biomagnify in the food web (Teuten et al. 2009). This means that those at the top of the marine food web are at the greatest risk of exposure (Man et al. 2016). That's where we eat.

These preceding statements are scientific, culled from research designs, published work, and conversations with our fellow scientists. As STS scholars such as Lorraine Daston (e.g., 2007) who study objectivity have taught us, these sources are not perfect vessels of truth so much as ways to construct worlds and realities. But those worlds are not settled and monolithic. They are our main building blocks as scientists, and they can be curated, arranged, and taken up in a way that reflects our obligations to emplaced relations. In Newfoundland and Labrador, marine mammals, birds, and fish are a mainstay of diets for rural and Indigenous communities, often communities with high food insecurity (Nunatsiavut Government 2017; Lowitt 2013). This makes rural and Indigenous people more likely to be exposed to industrial chemicals via plastics because of their social, economic, geographic, and cultural location (Man et al. 2016). We orient our scientific facts to this concern. Charlie remembers,

> During the recreational food fishery, when people in Newfoundland can fish legally, we go to the wharfs where people are filleting their fish and ask for the fish guts. Sometimes commercial fishers are also at these docks, and we ask them as well. We get guts from hundreds of fish this way every season. This approach to data collection aligns well with our commitment to accountability and to good relations. Legally, cod must be gutted on the wharf and cannot be processed at sea. Fishers, both commercial and recreational, typically discard the guts into the sea around the wharf, keeping the tasty fillets, cod cheeks, and britches. So our data comes from something that has to be processed on the wharf, is not normally used by humans, and would have been thrown away. This is good.
>
> But in our second year of data collection on the wharfs around St. John's, someone else wanted cod guts. We are bagging and tagging the pile of fish guts on the table in front of us, gathered from a group of fishers that have landed fifteen fish. An old woman approaches us.

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Her accent is thick and we have trouble understanding what she says at first. She wants the cod guts. She wasn't interested in the guts for scientific purposes. She didn't want to know how much plastic the cod had ingested. Instead, she wanted to use the cod carcasses to make a soup or a broth. We thought the cod carcasses and guts were waste, but clearly that is not the case for everyone. We were surprised and taken aback. What had seemed such an ethically uncomplicated way of collecting data had suddenly become deeply complicated. How could we take food away from someone in order to generate data in our lab? Taking food away from someone to produce data on marine plastics didn't align well with our commitment to good relations.

This case might not seem like a hard one to maneuver—we can spare a few guts. The fish and fishers are generous that way. Moreover, if our research focus is on food justice in the province, then saving guts for food instead of science is a direct way to contribute to that focus. It would enact good relations.

But it is a little more complicated than that. One of the ways feminist STS has thought about the pairing of relations and ethics is through theorizations of care. We can understand care as a mode of attention that gathers and holds things together, thickening and multiplying how things are related (Puig de la Bellacasa 2011), supporting a way of research "whose import will no longer be to debunk but to protect and to care" (Man 2004, 232). Some STS feminists have argued for ethics of care as relational entanglements based in practice (making & doing) rather than only in theory, including how we acknowledge and respect our situated relations even when those relations are not the ones we desire or choose by our own designs, such as suddenly being in relation with a woman on the wharf who wants your guts (Murphy 2015; Martin, Myers, and Viseu 2015).

At the same time, Michelle Murphy reminds us about the histories in which care marks out certain bodies as sites of intervention. She warns us that acts that are often framed as benevolent gestures of care in fact maintain power relations, including colonial ones (2015). Any impulse to think about our relations to fish, fish guts, fishers, women on wharfs, and science as one of care is complicated by this reminder. We did not care for the woman on the wharf by giving her guts—that would be deeply paternalistic, first by assuming that we *could* care for her and second by framing ourselves as benevolent gift givers of what she needed and what the fish already gave. More likely, we interrupted her carcass collection and made her day more difficult. Perhaps she was caring for us, these scientists ruining perfectly good food. Nor did we care for the guts. We were careful with them, but we also took them. We took them away for our own uses, our own desires and goals, benevolent as they may be. Calls to rearrange technoscience in terms of care or concern, Murphy writes, are often framed as "a romantic project that tend[s] to emphasize the liberating potential of a politics of positive feeling. It tend[s] to avoid addressing the ongoing, painful and extensive forces of racism or colonialism that do not disappear with good intentions or by constructing spaces where such forces are not keenly felt by privileged subjects" (2015, 720). The woman on the wharf interrupted our privileged subjecthood.

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And so it is our obligation to address "the ongoing, painful and extensive forces of racism or colonialism" in our practices.

In our case of encountering the woman on the wharf, attending to colonialism means we notice that we had unproblematic access to fish guts as a resource for the taking, taking them away from their land and emplaced relations. Colonialism is a structure that ensures ongoing access to land as resource (Coulthard 2014) for colonizers and settlers, including access to soil, water, air, fish, and their guts for science. The issue is not that there are more than enough guts to go around, or the generosity of the fishers who give us guts, but the assumption of access and that our access precludes other access, uses, and relations (Whyte 2017). If the woman who wanted the guts had not been there, the guts would probably have gone into the water, to crabs and sculpins. What would an anticolonial sample collection be in this case? Not collecting? Asking politely? Learning that "politely" in this context might mean including the crabs and sculpins?

We're working on that.

LESSON TWO: RELATIONS ARE NOT ENTANGLEMENTS (DISPOSING OF WASTE)

We take the guts back to our lab; open them up; look for plastics and count, weigh, and measure those plastics; and then we archive the plastics in pretty glass vials. There are stories about these processes, but we want to focus on scientific practices that often don't receive attention (following Puig de la Bellacasa 2011). Once the guts are emptied of their contents, what do we do with them? Initially, following university health and safety protocol, we incinerated them as hazardous waste, the same treatment as for all other animal tissues used in scientific studies. We are committed to expanding how fish are known in a university setting, not only as samples but also as food, political citizens, and grandmothers, so we petitioned the Institutional Biosafety Committee to reclassify the guts as food rather than biohazardous waste, which they granted readily. One of the things about compromised fields is that you find allies everywhere, often in unexpected places. We aren't the only ones at the university trying to do good relations (la paperson, 2017)! With the Institutional Biosafety Committee's support, we can put our guts in the dumpster, as though food scraps. But this option did not seem particularly feminist or anticolonial in terms of enacting equity, reciprocity, or humility (you don't put your kin in a dumpster!), so we held a lab meeting (the first of many) to consider the problem. After the meeting, Edward went away thinking about what to do:

> I asked my Elder about sharing animal guts. After several moments he shared a memory starting in his childhood. It was my memory as well, and undoubtedly the same memory his Elder kept. When I was young, I was told to take what remains over to feed the dogs, or the birds in the summer months, and these other ones to another place so that the mice might

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enjoy them. Some were left to be reclaimed by the waters and all that lived below them and some to go into the ground. As the memory travels through the generations, the only difference was how much there was to take. There was no such thing as waste. All was consumed by us, the animals we shared the land with, or the land itself. Everything is in movement. Even things that were still were gone by morning. Spreading around what remains ensures that they are shared efficiently and that no remains are piled to the point of contamination. And while the delicacies found in entrails have been forbidden to me because of PCBs and other things from away, the remains still have purpose in the larger whole. They are part of sila and keep me, my Elder, and my Elder's Elder buoyant.

In this story, the relations are spread out across many beings, and obligation comes with those relations. These relations are not synonymous with "relationship" or association. In much Indigenous thought, relations do not arise from association or processes (Watts 2013). This makes Indigenous STS different from the relational accounts of Actor Networks, matters of concern, and care we described earlier. As the Anishnaabe and Haudenosaunee STS scholar Vanessa Watts argues, models of relationality such as those represented in Actor Network Theory, or the parceling of humans and nonhumans as distinct but relating entities in multispecies relations, "removes the *how* and *why* out of the *what*" of relations (2013, 24). It divides epistemology from ontology (and certainly axiology, or ethics), even if they remain intimate. In these theories of relations, "objects, actants, or beings in the world may have an essence or an interconnection with humans, but their ability to perceive is null or limited to instinctual reactions" (24). In these relations, "humans are responsible to land the way an owner might be responsible for a pet" (29). Not cool, says Watts. That sounds like a violent type of care, says Michelle Murphy. Okay, we say. We believe you.

Put another way, in much Indigenous thought, ontology, epistemology, standpoint, and axiology are different expressions of the same thing (Wilson 2008; Walter and Anderson 2013; Chilisa 2011). The *what* is always already a *why* and a *how*, which is another way to say "obligation." *This is what we mean by relation*. Shawn Wilson argues that "the shared aspect of an Indigenous ontology and epistemology is relationality (relationships do not merely shape reality, they *are* reality). The shared aspect of an Indigenous axiology and methodology is accountability to relationships" (Wilson 2008, 7). In a cosmology based on relationality as obligation, "right or wrong; validity; statistically significant; worthy or unworthy: value judgements lose their meaning. What is more important and meaningful is fulfilling a role and obligations in the research relationship—that is, being accountable to your relations" (77). As scientists, researchers, members of communities, and people with land relations, we have certain roles and obligations to fill when we are left with a bag full of fish guts. We do not choose those obligations. They are already there. Perhaps you could say that they choose us, like kin. Protocol is supposed to help you maneuver those obligations.

Now we bring our guts back to the water and share them around, back to the sculpins and crabs. It's called a repatriation protocol rather than a disposal protocol.

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But we keep working on it, because relations are in movement, as the Elder said, and we are not done. There are still years, probably generations, of work to do on this protocol. Is it okay to return char guts from Nain to the Gut in St. John's? Is it okay to return a freezer-full at once? What sort of ceremony should we be doing to help with the orientation, if any?

LESSON THREE: RELATIONS ARE UNEVEN AND INCOMMENSURATE (GIVING CREDIT)

There are relations between the humans in the lab as well. One of the concrete ways that CLEAR foregrounds our obligations to each other and to equity is in our author-order protocol (Liboiron et al. 2017). We are obliged to recognize, celebrate, and support one another to succeed in our chosen professions, which means publishing in traditional scientific venues, and we aim to do so equitably and with humility. Norms for naming and ordering authors in the environmental sciences give most credit to the first author, who is understood to have guided the research in terms of ideation and labor, and the last author, who is understood to have mentored all authors. Because credit is not even, author order matters. At the beginning of the chapter we said that making & doing brings ethics into view in a way that sitting at your desk may not. But we are still in relation at our desks, writing. We are still intervening in lives through writing, and so it is a place for ethics (see Smith 1999; Deloria 1969). We're sure this is something that readers have experienced. Our author-order protocol, described in the following, is meant to travel and be helpful to readers who we know are compromised as we are, in a field where publishing, value, and equity are not always aligned (our citations are an experiment in a similar effort).

CLEAR's author order protocol foregrounds equity, by which we mean attending to the uneven social locations of lab members, rather than equality, which would involve treating all lab members the same. First, we work to recognize forms of labor that are usually left out of scientific articles, such as cleaning, organizing meetings, and other care work. Here we are indebted to feminism's insights into unpaid domestic labor and STS scholars such as Maria Puig de la Bellacasa (2011) for bringing those ideas into scientific practice. Second, we consider people's social locations. For example, junior CLEAR members, often undergraduate students, may never be on a paper again. Women, people of color, Indigenous people, people with disabilities, and people from low-gross-domestic-product countries are most likely to be overlooked in merit-based awards, pushed out of science, said to complain too much, and have their ideas stolen (Smith 1999; Ahmed 2017; Todd 2018; and our own experiences). When authors are considered to be equal in terms of labor, these folks are bumped up in author order in terms of equity. CLEAR's author order process occurs through a lab-wide consensus achieved during facilitated lab meetings (the full protocol is in Liboiron et al. 2017). Emily recalls:

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I'm in the lab with fourteen other lab mates, seated around a table that's topped with baked goods to nourish our bodies while our brains attempt to decide the author order of our newest plastic ingestion study with silver hake. We're listing types of labor involved in the project so we can be sure to credit everyone who has been part of it. The list includes collection work gathering the fish, processing samples, writing, editing, organizing meetings, cleaning up, and grant administration. Now we're adding another one. All fingertips reach skyward and wiggle: jazz hand consensus around the table. This is how we show agreement. We've all agreed that dying is a form of labor and it is worthy of a star—meaning it is among the most important forms of labor in this project. Labor means authorship credit. Max, who's facilitating, adds "Fish" and a star-like scribble to the list of potential authors on the whiteboard, because fish are the ones who did the dying. I grab an extra granola cookie.

Including dying as a form of value-adding labor puts "dying" alongside "cleaning" and "editing" on the list of scientific activities. It's a lopsided list. This is the thing about relations: they are uneven, even incommensurate, in how they add value, how they give and take, sustain and sacrifice. Sometimes people understand reciprocity—one key characteristic of good relations as they've been taught to us (Dorion and Flamand 2011)—as a barter in which one good practice is met by another of commensurate value. But if we take equity and Murphy's work on feminist care seriously (2015), we know reciprocity will always occur within and across deeply uneven social locations and histories. If we extend this relation to fish that die for food and science, then the idea of reciprocity as parity is off the table entirely—an equal trade leaves everyone dead or hungry. Robin Wall Kimmerer writes about the combination of reciprocity, obligation, and unevenness in relations: "If I receive a stream's gift of pure water, then I am responsible for returning a gift in kind. An integral part of a human's education is to know those duties and how to perform them. . . . Humans have the capacity for gratitude. This is among our gifts. It's such a simple thing, but we all know the power of gratitude to incite a cycle of reciprocity" (2013, 116). We can never match the generosity of water or of fish, but gratitude is part of our obligation to those relations. Moreover, fish likely don't care about author order. Or at least the value of authorship does not accrue to them the way it does to a human lab member. But relations are not about value parity—they are about obligation.

Even in these uneven relations between fish that died and lab members, there is compromise. In the end, the fish in Emily's account were not included as authors in the final submitted scientific article (see Liboiron et al. 2018). We left them off the author list because we still need to be published as scientists, which means following the norms of science in which only humans are considered authors. But we still wanted to show gratitude, so in the acknowledgment section we thank "Susan Fudge and Laura Wheeland for coordinating the Celtic Explorer survey trip, and M. Bilinearis for their personal sacrifices to the project." The Latin name for silver hake is *Merluccius bilinearis*.

But what about this chapter? We can finally give fish author credit for the work they do because we're publishing in an edited volume on making & doing! Our

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editors don't care if we have fish as authors. It was an exciting lab meeting. Max took notes:

The lab discusses putting the fish as first author. A lot of people are for that. People are excited, there is wiggling in seats. But then the tone changes. Charlie asks, "What relation are we setting up if we gift the fish authorship?" Nicole tells a story about being interviewed as a Newfoundlander for a book and how she would never want to be coauthor on that. Charlie tells a story of a professor who published a student's term paper, and though the prof gave the student author credit, the student did not give consent to be published or be an author. Elise talks about how survivors elevate their cultural status by obituarizing the dead, using the names of the dead as capital. Taylor says, "Giving the fish author credit is in the spirit of the paper," but as a group, we come to realize it is also wrong according to the lessons of the paper. "So," I ask the group, "how do we want to credit the fish, then?"

We have an obligation to the fish for their part in our learning, but we are reminded of Murphy's lesson that care can also be violent. Authors are obliged to their papers. The gift of author order would oblige the fish to the paper in a way that is out of place, without consent, trying to make commensurability where there is none. We must meet our obligations to the fish in other ways. We decide to acknowledge them as teachers, and all our teachers, in a space that is less than author credit but more than a traditional end-of-the-paper and often unread acknowledgment. You can see our compromise on the first page of the chapter, in the endnote, and in the author biographies.

LESSON FOUR: TENSIONS AND COMPROMISE (KILLING, TALKING, BRAIDING)

I told one of my friends about the disaster of trying to kill char in Nain. He laughed. He spoke about his first moose kill and what a disaster it was. When you're learning, you can't do good relations well. You're not good enough at it yet. The animal suffers, you suffer. Blood is everywhere. Your teacher pretends to be looking somewhere else. But this is learning. It is not possible to be in good relations without this learning.

I was giving a talk about CLEAR's feminist science at a university reputed for its progressive politics. It hosted one of the most alienating Q&As I've ever been invited to (except for that time in that philosophy department). One question stood out. A woman asked me to share my failures in the lab. I asked what she meant. She said, "I want you to be more vulnerable." I obliged her. Later, I was furious. Furious for the question—asking me to be more vulnerable, standing at the front of the room as a small, Native woman whom academia and dominant science are built to erase, trying to work where there are few roadmaps. I was furious no allies in the room stepped in to intervene, despite their rhetoric of allyship. But mostly I was furious at myself for obliging instead of burning that house down.

In braiding sweetgrass—so that it is smooth, glossy, and worthy of the gift—a certain amount of tension is needed. Any[one] with tight braids will tell you, you have to pull a bit. Of course you can do it yourself—by tying one end to a chair, or by holding it in your teeth and braiding backward away from yourself—but the sweetest way is to have someone else hold the end so that you pull gently against each other, all the while leaning in, head to head, chatting and laughing, watching each other's hands, one holding steady while the other shifts the slim bundles over one another, each in turn. (Kimmerer 2013, ix)

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We hope our stories show that a dedication to good relations, in or out of science, is fraught, ongoing, and emplaced. This is why methodologies of making & doing are well suited to theorizing ethics-as-obligations-as-relations. Some people will call these politics (and we agree), but we prefer to call it obligation, because it favors a scale and specificity of action that has to contend with whether and how to kill a fish while being a guest on a boat in Nunatsiavut with a dull knife. Politics might accidently miss that scale.

The three stories that open this final lesson are about different ways of approaching the ongoing task of obligation to relations in an uneven terrain. Some look more like what we've been calling compromise, in which there are no good options available and we must pick our way through the less-than-ideal landscape, whereas others are more about the conditions of building a livable world together with others, but they all share the same seed. In all cases, ethics are a lot of work, and it's in the doing.

CLEAR's work, which takes up lessons from feminist STS and Indigenous scholarship, has solidified two ideas for us that may be useful for other scholars. First, relations, ethics, and obligations are best enacted as synonymous. This brings together epistemology, which is a way to talk about ways of knowing; ontology, which is about "the conceptual nature and relational classification of objects and beings" (Brighten 2011, 52); axiology, which is a way of talking about values and goodness; and standpoint, which names the relationality of personal and collective experiences, histories, and social standing that is foundational to feminist standpoint theory. All four happen simultaneously, so the what, how, and why are the same thing (Chilisa 2011; Watts 2013). Although STS scholarship increasingly refers to relations (a search of English-language articles in *Social Studies of Science*, *Science as Culture*, and *Science Technology and Human Values* returns 295 articles with "relations" or "relationality" in their abstracts), the term is rarely paired with ethics, obligation, and axiology as a necessary bedfellow (of those 295 texts on relations, 19 had "ethic" in their keywords list). We argue that relations and ethics are always and already the same things.

Second, we have worked here to describe and texture relations and what they are, an act we hope other STSers take seriously when they talk about relations. That word flies around a lot at conferences, but it's hard to know what it means. Relations are never in the abstract. They are specific. We've argued that they are not entanglements but are part of ontologies; they are not processes but are orientations to obligations; they are uneven and incommensurate; they are ongoing and emplaced; they can cause harm or be in good standing. Most importantly, from our positions as feminist and anticolonial scientists, relations are compromised. Being in good relations is about maneuvering the "discrepancies, ambiguities, and paradox" of being a feminist and anticolonial in a Western scientific laboratory and "trying to force fit the world into available political ideologies" (Fortun 2009, 51). Compromise does not refer to acts that are wrong or damaging, although it could. It means that, because we are in diverse, multitudinous, simultaneous, thick relations and thus in

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contrasting, aligned, and incommensurate obligations, we are always meeting some obligations while not meeting others. It is about the choice to continue to slit the throat of the fish with a dull knife, even though it is shitty. It is about taking the incommensurabilities of giving author credit to fish seriously.

EXPERIMENT ONE: CITATIONAL RELATIONS (THE REFERENCES LIST)

CLEAR is part of a growing movement to build a better world by citing it (Ahmed 2013; Ahmed 2017, 14; Gaztambide-Fernández, Tuck, and Yang 2015; Mott and Cockayne 2017). Citations are locations. They situate us as scholars in terms of disciplinary habits, techniques, and lines of inquiry and, of course, enact relations. Our references list is an attempt to disrupt the disappearances and erasures that sustain the patriarchal and colonial infrastructure inside and outside the university, to build good relations in writing. Welcome to our experiment! You may have noticed as you read that we are following radical-shit-disturber Sarah Ahmed when she says, "I adopt a strict citation policy: I do not cite any white men" (2017, 15). Max remembers:

> Reading that sentence in Ahmed about not citing any white men. I nearly dropped the book. I remember thinking: you can do that? Then . . . how do you do that? I tweeted something about it to scientists, and the responses were, like: "do you mean the lead author, or all authors?" Scientists are so practical—right back to protocol!

Ahmed clarifies that not citing "any white men" is not about defining which individuals are white and men—you're in, you're out—but that "by white men I am referring to an institution. . . . I cite those who have contributed to the intellectual genealogy of feminism and antiracism, including work that has been too quickly (in my view) cast aside or left behind, work that lays out other paths, paths we can call desire lines, created by not following the official paths laid out by disciplines" (2017, 15). CLEAR is engaged in several experiments in citational politics, and this is one of them. Here, we richly cite "those who have contributed to the intellectual genealogy of feminism and antiracism." To a lesser degree, when we invoke those who write for and reproduce Institutions, we have cited them as such, using "Man" in parenthetical citations, collectively accruing to "Man, White" in the reference list, regardless of their gender expression.

The final step of this experiment is that we have not ordered our citations alphabetically but according to whom we owe a debt of gratitude, arranging them the same way you feed Elders and teachers first at a feast. This arrangement is our "thank you" list to some of those who have fed us and whose shoulders we stand on. Thank you.

CONTRIBUTIONS

Max Liboiron collected stories, coordinated lab meetings, and did the majority of the writing and theorizing. Emily Simmonds conducted literature reviews on feminist

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STS and care and on Indigenous STS. All other authors contributed the first-person narrative stories around which this paper is built and put trust in the lead author. All authors were involved in editing. All our teachers precede and exceed our learning, writing, making, and doing.

ACKNOWLEDGMENTS

We respectfully acknowledge the territory in which this research was conducted as the ancestral homelands of the Beothuk and the island of Newfoundland as the ancestral homelands of the Mi'kmaq and Beothuk. We recognize the Inuit of Nunatsiavut and NunatuKavut and the Innu of Nitassinan, and their ancestors, as the original peoples of Labrador. We strive for respectful relationships with all the peoples of this province as we search for collective healing and true reconciliation and honor this beautiful land together.

This research was supported by SSHRC grant 435-2017-0567, "Placing Science: Implementing Feminist, Indigenous, and Decolonial Theories of Place and Land in the Laboratory."

We give special thanks to CLEAR members who reviewed this text and participated in three author-order meetings: Grandmother, Kookum, Nicole Power, Nadia Ivette Duman, Marisa Van Harmelen, Elise Earles, Alexandra Hayward, Natasha Healey, Nic Kuzmochka, Ignace Schoot, Hillary Bradshaw, Jacuelyn Saturno, Katharine Winsor, Lucas Harris, John Atkinson, Taylor Stocks, Justine Ammendolia, Kelechi Emmanuel Anyaeto, France Liboiron, Kaitlin Hawkins, Taylor Hess, Noah Hutton, and Iwalaye Oladimeji (Ayo).

We are only the authors we are because of our teachers. We give a special acknowledgment to Arctic char, Silver hake, Atlantic cod, the boat driver, the woman on the wharf, our Elders, the editors, our reviewers, and all our teachers.

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7

THE ART OF STAYING WITH MAKING & DOING

Exnovating Video-Reflexive Ethnography

Jessica Mesman and Katherine Carroll

Very cool, very nice! I am impressed by what we do every day. It's pretty complex and it's amazing that we do not make more mistakes. It is like Grand Central. There is so much going on. The Breast Specialty Council is working on trying to standardize all aspects of breast cancer care from screening through treatment for metastatic disease and I am just struck by how much of this work is already standardized. It is almost like a symphony where you have these people with this intense concentration doing their expert job in the midst of thirty people doing something with a different part of the symphony. So, it's fascinating to me, the degree to which it is already standardized and the degree to which it may not be standardizable, because it depends so much on these intensely personal communications about the individual patient.

These comments are spoken by a breast cancer surgeon during a video-reflexivity meeting where she and her clinical colleagues gathered to review video footage of their own practice as part of a study on interprofessional collaboration. The surgeon is "impressed" by what she sees and finds it "fascinating," and she uses the similes "Grand Central" Station and "symphony" orchestra to capture the clinical dynamics that the footage reveals. The event she describes arose from one of our projects in which we combine research with practice improvement in close collaboration with practitioners.[1] A growing number of STS scholars use various methods, captured under the conceptual umbrella of making & doing, to make a difference in the practices they study. In this chapter we discuss the method of video-reflexive ethnography (VRE) as one approach to STS making & doing in the midst of others that are presented in this volume.

By using VRE we aim to make and do with a lasting effect on practice. Yet to leave a sustainable mark on the ecology of practices requires methodological rigor. Traditionally this rigor is externally defined, inflexible, and applied before arrival in the field. Our rigor, however, comes over time and is generated on location from within the field. Whereas practice optimization acts as our end goal, navigating toward it

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produces "collateral realities" (Law 2012) that require our attention as well. Methodological rigor, it turns out, comes with mess and vulnerabilities for all involved. In this chapter we discuss the methodological rigor that making & doing through VRE requires.

Before we dive into the matter, let us briefly introduce ourselves. We, the authors of this chapter, are (if we may say so) highly experienced hospital ethnographers in different kinds of critical care units, such as intensive care units, emergency departments (EDs), and operating rooms (ORs). We both work in the area of safety. Jessica's work has a strong focus on why things go well despite the complexity of practices. She is fascinated by the importance of the mundane in stabilizing health care practices. She considers the ordinary to be an expression of a successful career of things and processes as because it proves their high level of integration in the fabric of practices. Katherine's work promotes the vital relationships, emotions, materials, and practices that constitute perinatal women's health care. By highlighting these aspects, Katherine seeks to attribute greater value to these gendered blind spots that are critical to medical care delivery and research. For more than a decade we have "made our hands dirty" (Bijker 2009, 11) and used VRE as an interventionist and collaborative method to make a difference in health care delivery. Together, despite residing on different continents, we have practiced VRE in Australia and the United States as a research team. Through our engagement with health care practices we have learned a great deal about the clinical spaces we study, and we have also learned a lot about how our professional biographies affect our ways of doing research (Carroll and Mesman 2011).

Before turning our focus to methodological rigor, we first elaborate on our main instrument for making & doing: VRE. Although aiming to make a difference and using the VRE method is not the exclusive domain of any field, the STS approach brings in specific features in doing so. Therefore, we also explicate how STS contributes to our way of making & doing practices. Conversely, making & doing projects can also contribute to the field of STS. Such contributions deserve our attention as well.

VISUALIZING MAKING & DOING

An STS approach to interventionist research positions practices at the center of its attention and articulates, among other things, their complexity, nonlinearity, and coconstructive hybrid and dynamic characteristics. Furthermore, the counterintuitive reasoning embedded in STS thinking acknowledges the importance of what is traditionally neglected, diminished, or ignored in more traditional practice improvement projects. For example, in the STS framework the mundane is not ignored but instead considered worthy of unpacking and learning from. The ordinary can be considered an extraordinary accomplishment. Ordinary daily work, as it turns out, is not a simple routine but rich and resourceful. Likewise, informal practices require

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our attention because they are the glue that holds practices together. The counterintuitive way of reasoning also makes us aware of the potential of ambivalence and inconsistency in preventing practices from stalling. In other words, framing interventionist research in an STS way makes us ask different questions; it empowers us to switch lenses and see things differently. As a consequence, it articulates that "what is" has the—again, counterintuitive—potential to turn into "becoming." Becoming harbors an openness with the potential for improvement.

The act of foregrounding what is already there to improve practices is captured in the concept of exnovation (de Wilde 2000). "Exnovation" is an aggregation of "excavation" and "innovation" (Iedema, Mesman, and Carroll 2013, 10). Excavation refers to "exposure of what is already there" and to "digging out" (10). As a product of counterintuitive reasoning, exnovation aims to excavate and articulate the existing strengths within practices. In this way exnovation sheds light on the resourcefulness and creativity of professionals in their effort to produce an up-to-standards performance in the complex dynamic of their work environment. It offers insights into their specific modes of ordering day-to-day practices (Law 1994). Exnovation, in other words, explicates competencies of coordination and alignment of modes of ordering that professionals are not always aware of (Mesman 2008). Explications of hidden constituents of practices exposes not only the complexity of practices and creativity of professionals but also the limited power of technology and formal protocols to ensure the continuity of practices (Mesman 2008). Opening up ordering processes of practices as well as studies on invisible work are well-established research topics within STS.

By exposing what is already there, exnovation acknowledges that these unarticulated actions are not only a crucial resource for the accomplishment of work but also opportunities for improvement. In its counterintuitive way, exnovation explicitly aims to improve practices by paying attention to what is *already* in place (Mesman 2011). Thus, an exnovative approach challenges (locally) dominant images of practice improvement that tend to ignore existing practices as vital resources for optimization (de Wilde 2000). Exnovation, in other words, is "innovation from within" that does not deny complexity (Iedema, Mesman, and Carroll 2013).

Our conceptualization of exnovation focuses on hidden or forgotten resources. This positive direction sets it apart from the negative version of this concept, which refers to scaling back or even taking out procedures and practices that hamper innovation. Exnovation as abandonment of existing practices to support performance improvement can be found in, for example, environmental science (e.g., Hermwille 2017; Heyen 2017), studies on innovation management (e.g., de Hoop, Pols, and Romijn 2016; Frost and McHann 2015), or health science (e.g., Rodriguez et al. 2016). We, in contrast, have adopted the version of Rein de Wilde (2000), a philosopher of science, which fits the counterintuitive way of reasoning. Compared with management and environmental literature, our use of exnovation is not aimed at taking

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away but has its focus on the potential of existing practices in order to maintain, elaborate, and learn from these practices.

Paying attention to the local routines that have become invisible, hidden, or simply forgotten raises the question of how to identify these potential resources. This, we argue, requires not only insider knowledge to recognize them but also a distance to defamiliarize the usual and be able to see them in the first place. It requires a "situated distance" in which the familiar and the unfamiliar coincide (Carroll and Mesman 2018, 1152). It is here that VRE comes into play, because it enables practitioners and researchers to recognize how their everyday routine activities are an extraordinary achievement that culminate in the delivery of complex, dynamic practices.

VRE is a collaborative visual method used by researchers and professionals to understand, interpret, and optimize professionals' work practices (Iedema, Mesman, and Carroll 2013).[2] VRE is both a research method that seeks new knowledge conveyed through standard scholarly outputs and an intervention in local work practices in order to create new learning and even optimize work.[3] The VRE method achieves research and intervention aims through involving either researchers or professionals in filming day-to-day work and showing select footage to the professionals during video-reflexive sessions. A video-reflexive session provides participants the opportunity to view video recordings of their work (the taken for granted) in a way that offers them a new perspective (Iedema et al. 2009b). Maintaining the twin goals of scholarly research and local intervention, video-reflexive sessions generate a (re)awareness and (re)appreciation of daily routines by all involved—that is, both the professional participants and the researcher participants (Carroll et al. 2018). Thus, an important aspect of VRE is its exnovative capability: foregrounding what is already there but forgotten. For professionals, such (re)awareness and (re)appreciation of daily routines gives rise to an impetus to change, to invest or to optimize in ways of doing (e.g., Carroll, Iedema, and Kerridge 2008; Iedema and Carroll 2013). During video-reflexive sessions the researchers and professionals coanalyze the video clips in group discussions. These discussions are recorded, and the outcome of the discussions acts as further research data in addition to providing fodder for new insights and practical suggestions (Iedema, Mesman, and Carroll 2013). In other words, we consider VRE as making & doing par excellence because it combines a genuine engagement of the field of study with reflexive learning. Thus, in this casting of VRE as a possible means for making & doing, we see it as an approach to making a difference that encompasses three interrelated and often iterative phases (filming, reflexive discussions using video footage, and data collection and analysis and optimization), which seek to achieve the two aims: improvement and research. In this way VRE distinguishes itself from other visual methods, such as ethnographic film that aims to transmit anthropological insights (Ruby 2005). These films are clearly not produced to generate reflections and discussions among participants as in the case of VRE. Likewise, ethnomethodological video analysis (Sormani et al. 2017)

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shares the focus on the mundane resources hidden in everyday life, but its ambitions are motivated solely by research, whereas VRE also includes practice improvement. Although visual anthropology (Pink 2013) includes video reflexivity as part of its method, it misses the parallel development of research *and* practice optimization. It is the specific configuration of characteristics like footage generated for the purpose of reflexive learning, participants acting as coresearchers, and the interrelated aims of academic research and practice optimization that differentiates VRE from other visual methods (Carroll and Mesman 2018).

VRE can be approached by the researcher in a number of ways.[4] First, as a "clinalyst." This notion, coined by Iedema and Carroll, is shorthand for "outsider-analyst catalyst" (2011, 176). The clinalyst catalyzes insiders' knowledge by asking outsider questions while collaboratively recording and viewing video footage with professionals. The clinalyst is in an excellent position to question dominant understandings and generate reawareness and redefinition of the daily experience of professionals by bringing in the counterintuitive way of reasoning that characterizes STS. The second approach can be described as engaging affect as method, which foregrounds the value of VRE researchers' precognitive affective engagement with professionals and highlights the crucial role that the affective enrollment of the researcher in the team plays in achieving VRE's twin goals (Carroll and Mesman 2018). Third is a planned obsolescence approach, in which the researcher facilitates but ultimately leaves professionals as independent users of VRE as an established infrastructure in their daily practices (Carroll and Mesman 2018). Regardless of the researcher's approach to VRE, VRE turns professionals into coanalysts by blurring the boundary between the researcher and professional participants. In VRE, professionals act as coresearchers from the very start because they are involved in the research agenda, the collection of video data by selecting the situations to film and where and when to film, and the analysis of the footage during the reflexive sessions.

As indicated earlier, STS frames the way we can make & do.[5] Although one can try to make a difference in many ways, STS framing in our case has contributed considerably to our video-reflexive way of making & doing. For example, by infusing VRE with the counterintuitive notion of exnovation, our interventionist research has a strong focus on the here and now and on the positive and informal aspects of practices as potential resources for improvement. In effect, we make practitioners aware of the importance of their mundane practices and therefore suggest that some of their daily routines, such as putting on sterile gloves, be filmed and analyzed collectively. The STS tendency of counterintuitive reasoning makes us time and again turn to capabilities instead of inadequacies and ask the question "Why do things go well, despite a complex work environment, shortage of staff, and sometimes-fallible technologies with incompatible procedures or unrealistic demands?"

STS enriches the VRE method with new ways of understanding and acting, but VRE also has much to offer STS. For one, exnovation has been adopted and further

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developed by the VRE community into its methodological program (Iedema, Mesman, and Carroll 2013). Nowadays, exnovation is one of the four guiding principles of VRE (Iedema et al. 2019, 12).[6] This indicates how the travels of STS knowledge inflect knowledge formations and knowledge making in another field and how STS knowledge itself gets transformed in the process. Let us take a closer look at what our VRE way of making & doing has on offer for STS.

MAKING & DOING AS A PASSAGEWAY FOR STS

Making & doing projects can act as very effective passageways for STS knowledge to travel on. Downey and Zuiderent-Jerak (2017) stress the importance of alternative images, infrastructures, and identity as important building blocks of the passageway on which knowledge can travel. Making & doing projects can provide these building blocks and make STS knowledge travel to new settings. In our case, the locales are as diverse as operating theaters in world-leading clinics, control rooms of railroad companies, or midwifery practices in little villages. Such a passageway is important for bringing about basic STS tenets, like the situatedness of everything somewhere and sometime, going beyond the binaries and boundaries, taking into account materiality and its agency or the importance of articulating and questioning dominant ways of understanding while being open to alternative conceptualizations of the world in which we live. Here, to elucidate a possible path that STS knowledge can travel on, we use our study on interprofessional collaboration.

We used VRE to study interprofessional collaboration between a team of breast surgeons and a team of surgical pathologists in order to identify and further enhance their already successful interprofessional practices that contribute to their timely and accurate intraoperative evaluation of breast cancer specimens (Carroll et al. 2018). We focused on their communication styles and strategies in particular. Jessica positioned herself in the OR with a handheld camera and followed staff members carrying a resected breast specimen to the Frozen Section Laboratory of the Pathology Department. Here Katherine was waiting with her handheld camera and filmed the handover of the specimen from surgical staff, the communications associated with its movement through the evaluative stages in the lab, and the moment when the final result was called back to the OR. Meanwhile, Jessica returned the OR to film the moment the surgeons were informed via the intercom by the pathologist about the results. By using two researchers and two cameras across both spatial locales, we were able to capture the intra- and interteam communications associated with each team's contribution to the successful interteam evaluation of the breast cancer specimen.

A few days later, and after our careful selection of footage that displays moments of interteam collaboration, the surgical and pathology teams were invited to view and discuss video data of their own intrateam collaboration and communication practices. Then, a few days later again, the surgical and pathology teams were

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invited to view footage of interteam collaborations that depicted both the surgical and the pathology staff. Acting as chair allowed us to support participants in shifting their focus from the more traditional problem-based perspective to a strengths-based perspective and asking outsider questions. These discussions were video recorded and transcribed verbatim. These transcripts were deductively and thematically analyzed by us. In this way, our mode of doing VRE in this project involved two levels of analysis: the first is that performed by participants during the reflexive sessions, and the second is that performed by researchers when viewing the recordings of these sessions.

As part of the improvement trajectory embedded in VRE, participants were given the opportunity to identify what worked well. These reflexive moments made them aware how complex their work is ("like Grand Central" Station) and how they managed despite this complexity ("like a symphony" orchestra). A breast surgeon, observing a video of the work completed by pathology to provide a rapid intraoperative diagnosis to surgery, said, "And the other thing is how much more you guys are juggling in the lab, it's not just the [breast surgery] specimen it's all these other specimens coming and going and colorectal cases and gyn, and you know it's amazing that we do as well as we do" (Carroll et al. 2018). This statement displays a realization of complexity and also includes appreciation. Building on this interteam focus, watching the footage provoked each team to realize how much the work of the other team assisted their own team's workflow. To put it differently, a substantial part of the work of each team was intended to accommodate the tasks and responsibilities of the other team. Moreover, it turned out that their workflows were much more entangled than they had realized before. Pathology staff expeditiously call back diagnostic results to surgery. The lab team highlighted the efficiency of call backs as one way they facilitate successful collaboration with the breast surgeon team: "Communicating critical information back as soon as possible helps the surgical team know what to do. They know whether they need to re-excise the case, they know whether they are good, they can close or have plastics come in to do their thing" (Carroll et al. 2018).

In addition, the footage illuminated the value of everyone involved in specimen evaluation. All roles within the teams, regardless of hierarchy or prestige, were recognized as important for keeping the surgical practices moving (Carroll et al. 2018). As already shown, besides a reappreciation of each other's contribution, the participants also reconceptualized parts of their practice. For example, everyone had well-defined responsibilities within each team and clearly explained them to us during our orientation to the field. However, during the video-reflexivity sessions, they began to see that their collaboration has a highly valuable imprecise structure—a realization that opposed the linear and highly mechanized way in which they had previously characterized both the structure and the workflow of their work (Carroll et al. 2018). A pathologist told us, "So even though the specimen flows linearly, actually I think the

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[spatial] design is so that we can cross those lines anytime that we want and this lab in particular lends itself very well for that" (6). Although they had previously conceptualized their work as a linear flow, watching the video footage caused them to realize that pathology's achievement of a rapid and accurate intraoperative evaluation of the surgical specimens was actually based on their flexible, interdisciplinary, and cross-hierarchical web of communication and the specific material layout of their workspace (Carroll et al. 2018). Their exnovation in these reflexive sessions of what they already do so well instigated several initiatives by the surgical staff and pathology staff to further improve their interprofessional team communication. Pathologists and surgeons evidenced their redefined notion of success, shifting from primarily technology-based (high-tech lab instruments) to sociotechnical-based (lab instruments plus their own web of interprofessional communication) through the optimized changes they devised and implemented. We describe these changes in the next section.

This example demonstrates the potential to yield a reappreciation and a reconceptualization of participants, their interrelationship, and their work. The reflexive learning that is at the core of both making & doing and VRE provides a strong incentive for redefinition of practice.[7] Viewing one's own practices from a situated distance in the reflexive sessions provides participants a space for rephrasing dominant conceptualizations of their daily practice. It is during moments of reflexive learning that participants, like our clinicians, act as coanalysts and become aware of the situatedness of their work and how, for example, quality and safety of health care are iterative doings and not outcomes of standardized behavior. As a result of this awareness, VRE provides a platform for exnovating invisible work and questioning the solidity of facts and their construction in a way similar to an STS scholar. With this we do not mean that our VRE participants become akin to STS theorists. Instead, we mean that VRE enables them to see their practice beyond the dominant dichotomized images and question this taken-for-granted view. Thus, their reflexive sessions made possible knowledge transfer—that is, the STS project helped participants in seeing knowledge content in moments that they had previously ignored or not valued sufficiently, such as their informal interteam communication.

In sum, just as STS contributes to VRE, VRE has the potential to offer STS a fertile ground that allows notions, like exnovation, to develop into a methodology to open up practices in a counterintuitive way. Furthermore, VRE acts as a passageway that STS knowledge can travel on. What's more, our making & doing project provided us, as STS scholars, a way into day-to-day practices to reflexively learn about others and ourselves. STS scholars in their making and doing are, we argue, open to transformation—not just of the methodology and what that may do for the field site but also as scholars and coresearchers who have to do and redo practices in response to and as a result of their embeddedness in the methodology. Thus, our making & doing is more than the analysis of knowledge practices or practice optimization. It is also STS in action: as STS scholars, we are actively redefining practices, skillfully

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sensitizing practitioners, and emancipating by collaborating and working from the bottom up. In other words, making & doing is for us a way to open up the black box of doing STS. What kinds of insights does this yield? Where are the fault lines and frictions when being STS-ish? While making and doing we were forced to look carefully at what happens when our STS research and intervention practices met with the practices of those who would not necessarily characterize their work through the lens of STS, and then we had to subsequently deal with emergent situations or understandings. Reflecting on these moments therefore can yield insights relevant for the wider STS community.

MAKING A DIFFERENCE: NOW AND IN THE FUTURE

Practices of STS making & doing not only blur the boundary between researcher and participant but, as our example of interprofessional collaboration shows, also can dissolve the distinction between knowledge generation for the purpose of academic research and practice optimization (Carroll and Mesman 2018). Making & doing, we argue, offers us as STS scholars a *means* to enable professionals to engage with their own practices in new forms that provide ways of redefining problems, problem spaces, and timely solutions. In this section, we outline three interrelated aspects of making & doing through VRE: a fast track, a track into the future, and a solid track.

REFLEXIVE LEARNING IN THE NOW MAKES A DIFFERENCE

In terms of making a difference in the now, the surgeons and pathologists in our study made use of the video data depicting their daily routines and then their reflexive discussions that led to their new insights to further improve their collaborative practices. The counterintuitive turn of their focus toward the strength of their ordinary day-to-day practice shaped the intervention measures that the pathology and surgery teams derived for themselves and then implemented. These measures were based on reflexive learning, and as a result the teams decided to make adjustments to clarify their interteam communication practices. First, they sought to more clearly and consistently communicate the orientation of the breast specimen (once removed from the body) in relation to its origin (the patient's breast) by developing a written template to accompany the specimen. Second, they improved the call-back protocol by designing a standardized confirmation and validation procedure that applies for both teams (Carroll et al. 2018). Importantly, these improvements were implemented within a few months of engaging in VRE.

The study on interprofessional collaboration between surgeons and pathologists shows how exnovation and reflexive learning can provide new directions and practical suggestions for practice optimization in the here and now, because suggestions for improvement are generated in the reflexive sessions and can be followed up instantly

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(Carroll et al. 2018; see also Iedema and Carroll 2013). This immediate effect debunks the idea that scholarly intervention can contribute only somewhere down the line, following research reports that are supposed to have impact after the scholar has long left the scene (Grol et al. 2013). Fortunately, there is no need to wait for research evidence to make its way through peer review, publication, dissemination, and then implementation and change, because making & doing with the help of VRE provides a fast track.

VRE, as one example of making & doing, decreases the waiting time for impact because it removes the detour via research reports, policy notes, and implementation guidelines along which improvement initiatives have to travel. If successful, the impact of our way of making & doing happens while we speak in reflexive discussions that generate learning. Our VRE experience has demonstrated that concrete practice improvement can be implemented within a few months (Carroll et al. 2018; Iedema et al. 2019). In this way, making & doing projects can offer a fast-track intervention that enables us to make a difference in the here and now, instead of the estimated "17 years" from now (Morris, Wooding, and Grant 2011).

The idea of recasting intervention as something other than a linear process of design, data collection, analysis, and implication strongly resonates with STS sensibilities about the nonlinearity of knowledge and technology development. Expressed by Zuiderent-Jerak's (2007) notion "preventing implementation," making a difference is considered a form of ongoing reflection with a focus on the specific conceptualization and framing of everyday practice. Such reflections require a space in which the taken for granted can be questioned. Video-reflexive sessions are such a space. Here, in the dynamic and unpredictable flow of coproduced knowledge, new initiatives for change arise. Casting knowledge development as nonlinear implies that impact can't be scheduled into the future. Instead, it is scheduled in the present. Yet, making an impact in the present is one thing; making a permanent mark in the ecology of practices is another. We therefore describe the art of staying as it relates to planned obsolescence, one of the modes of doing VRE. Planned obsolescence has the potential to affect further travels of STS knowledge beyond the immediate moment. A significant detail here is that "change is in the first instance about exploring the soil from which innovations need to grow, more so than the innovations themselves" (Iedema, Mesman, and Carroll 2013, x). In other words, for STS knowledge to travel and have an effect in the present as well as beyond requires, first and foremost, a strong foundation. To underline the relevancy of the explorations of the soil we describe our groundwork (Phase 0) in detail at the end of this section.

THE ART OF STAYING BY LEAVING THE SITE

The dominant approach to practice improvement is based on the position of an external proposal by a change agent. However, in our VRE example, making & doing generates bottom-up improvement measures tailor-made to the local situation, and those involved are highly motivated to implement them. Thus, this form of making &

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doing contributes to self-governance through its reflexive learning. Self-monitoring through collaborative, structural reflection and the VRE mode of planned obsolescence provides the best option to empower professionals (Mesman 2015). Interestingly, planned obsolescence was never *planned* to be. Instead, it is the spontaneous outcome of our making & doing by clinician participants themselves.

Vignette: The Birth of Planned Obsolescence

Jessica was filming doctors and nurses for a study on patient safety in a Dutch neonatal intensive care unit (NICU). Together with a small team of clinicians (the video team), she selected the footage, organized and chaired the reflexivity sessions, and taped their discussions, thus making visible the unintended and unplanned patterns of backstage processes of "doing safety," which subsequently the clinicians could explicitly articulate. The discussions during the reflexive sessions proved to be relevant for her research project and provided the NICU staff an opportunity to improve their practice on a tailor-made basis. However, because of teaching obligations Jessica was not able to be present on the ward for several months in a row. During these months the reflexivity sessions were canceled because she was not there to prepare them. The reflexivity sessions were clearly dependent on her time and presence in the NICU. Everyone was frustrated that there were no reflexivity sessions while she was away. And so, during her absence, the members of the video team had taken action and made the method theirs. Jessica's absence, it turned out, had created room for a redistribution of roles and responsibilities that, in hindsight, has benefited the development of VRE method in an important way, because a new mode of doing VRE was born. (Adapted from Mesman 2015, 188)

The premise of planned obsolescence—that VRE ultimately becomes a structural element of the professional's teamwork—is that the presence of a researcher is ultimately obsolete. One may be concerned that without the presence of a researcher the scope and practice of VRE may be laid down only along normative lines as defined by those in positions of power. This is not the case. VRE is more than a bundle of audiovisual technologies. Not only is the locus of control and ownership of the project relocated from the researcher to the professionals themselves but so too is the mode of doing VRE—that is, the transformation of professionals into clinalysts who maintain a constant tension between critique, interpretation, analysis, questioning, and concluding (Iedema and Carroll 2011).

Planned obsolescence is permeated by the ideology of empowerment (Pink 2013) because it positions the participant at the center of knowledge production. To realize this ambition the researcher will facilitate professionals implementing VRE in a way that ensures the method becomes theirs. For planned obsolescence to be successful, training of professionals and structural resources, like time and thus money, are needed to secure methodological durability. Planned obsolescence results in a small number of professionals who form a team and come together at regular intervals to

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meet, evaluate, and organize their reflexive learning sessions and take the responsibility for videoing, facilitating the reflexivity sessions, and following up on practice optimization. Importantly, for STS knowledge to travel into the future, this team needs not only to master techniques of videoing and editing but also be able to prepare and chair the reflexivity sessions. This includes having the ability of a clinalyst to ask outsider questions and provide a counterintuitive focus that allows a questioning and redefining of the day-to-day practice. By turning professionals into clinalysts, we as STS researchers become obsolete and can leave the site. What stays behind as a structural mark is the attention for the untapped potential, for new ways of restructuring their working environment, and the act of constructively questioning dominant ways of working and reasoning about matters of fact and concern.

A FAST TRACK REQUIRES A SLOW ENTRY

Reflexive interventions, like our VRE studies, require a solid foundation to have a lasting impact. They require local adjustments and inclusion of professionals in the study design. Collectively, this means working with an evolving research project. Descriptions of this preparatory work remain a blind spot in the VRE literature.[8] Although much attention is placed on the use of the camera, the happenings during reflexive sessions, and key facets arising from data analysis, VRE's extensive time line is only alluded to. Here we acknowledge the groundwork upon which VRE rests in order to be successful. Only after this groundwork is established can researchers enter the field with a camera—that is, only when professionals are prepared for the visual medium to be used by researchers in their place of work. Thus, VRE is not about the power of the visual but the power of the visual that rests on the care and collaboration ingrained within the supportive infrastructure. Our claim is that preparation of supportive infrastructure is foundational for the success of the VRE intervention and therefore may also deserve ample attention in other STS making & doing projects.

Building supportive infrastructure can be thought of as a Phase 0—that is, before one really starts. Yet the term "Phase 0" could also mislead because it gives the sense that the phase is complete upon entry into the field. Preparation is not simply a stage before the start; it continues throughout the whole project. For example, researchers need to do iterative preparatory work to ensure that both the researchers and professionals and their practices are kept open for negotiation. Furthermore, researchers have to be sensitive about the needs and requirements of the practices they study and maintain relations with participants such that there is acceptance of being talked to, willingness to be filmed, and openness to change things during the entire project.

The preparatory work involved in VRE is varied and depends on the existing relationships with those in the field site and the type of VRE format.[9] However, preparatory work typically involves a myriad of practical tasks, education, and relationship building (see Iedema et al. 2019) as the following vignette reveals.

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Vignette: How We Enact Preparatory Work as a Methodological Principle of Rigor

The groundwork undertaken by Katherine in preparation for a VRE study in a large hospital in the US Midwest spanned the months that preceded seeking human research ethics approval and continued after approval was gained. First, after expressing her wish to combine her interventionist strategy of VRE in a high-technology area of women's health, Katherine was introduced to the *senior clinicians* in the breast surgery unit and pathology laboratory through a mutual colleague. The mutual colleague set the scene by endorsing the researcher and VRE. A formal meeting was instigated where Katherine introduced herself and the VRE method. To assist in VRE's introduction, she brought along copies of published peer-reviewed VRE articles in the area of clinical application (pathology) and the topic of interest (communication).

The clinician-stakeholders expressed interest in being involved and suggested that Katherine as the researcher present the project and method to the *broader clinician surgical team*. Katherine put together a short presentation that included photographic and video footage depicting how VRE was typically used. The senior clinical stakeholders scheduled a time for her to make her presentation and introduced her to their team. This had the effect of supporting the researcher and endorsing both her and her research to the team. The process was repeated for the pathology team.

Here we see that the clinical stakeholders are already becoming part of the research team much before the camera enters the field or footage is watched for coanalysis in reflexive sessions.

After approval in concept by the surgical and pathology teams, it was decided by the clinician stakeholders that the researcher must report to their *senior surgical management* to have in-concept approval for video in the operating theater. The researcher and representatives from the stakeholders attended a meeting with senior hospital surgeons and management about the project and answered questions.

With blessings in hand from the clinical side, it was time to return to putting pen to paper and apply for *human research ethics approval* through a collaboratively designed research proposal with clinical partners. The researcher drafted a proposal and the logistics of when to film, where to film, how much to film, who was to film, and the time line for filming and reflexive sessions was carefully negotiated with the clinical stakeholders.

To inform the writing of the research proposal, the researcher observed in surgery and pathology for three days to understand the workflow and physical layout of the would-be research setting. She made sure that clinician stakeholders were consulted as decisions were being made that might influence the practice. Human research ethics approval was granted.

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It may seem that this was many steps of administration and orientation. Yes, it was. However, equally importantly, these steps were about relationship building and providing collaboration, responsiveness, and trustworthiness on the part of the researcher, who was asking to be invited into the clinical space to film and engage clinicians' time in reflexive viewing of video footage.

> Once human research ethics approval was granted, it was time to disseminate the study to the *broader team*. The clinical stakeholders continued to support the researcher in this endeavor by arranging information-sharing sessions with clinical staff in surgery and pathology and being present to introduce the researcher and the research to the clinical teams. They remained present while the researcher made the presentation, fielded questions, and asked for initial consent. Their presence enabled senior clinical stakeholders to gauge how their staff were receiving VRE as a method and the researcher as a person who would be working closely with them in their workspace.
>
> After introductory meetings, numerous emails and presentations, discussions of drafts, five consent sessions across surgery and pathology, and researcher orientations to their clinical spaces, clinician stakeholders and clinical staff had already spent between sixty minutes and fifteen hours (depending on their role) in the presence of or having direct contact with the researcher before she even entered the field to begin the task of a VRE study.

This kind of information is usually left off the methodological detailing in published articles. We argue that in some making & doing projects, such as VRE, such infrastructure crucially supports the intervention. Downey and Zuiderent-Jerak (2017) stress that we need to take into account the "ecologies" that we encounter while making and doing. As the vignette clearly shows, the medical setting has a clear hierarchical ecology. Up, up, all the way up and down again, all levels have to be on board and require their own specific strategies and allies. Thus, the preparation is not a separate part—as in, before you start using XYZ, you have to do ABC—but a vital part of VRE as a making & doing project. Actually, Phase 0 is what turns professionals into coresearchers and, even more, develops a team of engaged coresearchers. For making & doing, this groundwork is both foundational and on location, and, as we argue in the next two sections, this local and immediate character of our way of making & doing comes with (un)expected opportunities and challenges.

COLLATERAL REALITIES

Having an impact, we argue, requires a solid foundation. Our previous account of the preparatory work done for the study on interprofessional collaboration suggests an orderly and methodological cleanliness. However, while actually doing research and the preparatory work that comes with it, we produce more than we are aware

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of. Making & doing could be considered as performative in its own way, and being performative, it creates "collateral realities" (Law 2012). How can we find out about the realities that we produce and their implications? The majority of our projects are completed on location, where our ways of making & doing are laid bare, in real time, in front of the professionals. What are the politics of the realities that we produce? Which distinctions do we produce? These important questions imply a situated exploration of our own unintended consequences.

METHODOLOGICAL FOUNDATIONAL IS DEEPLY MESSY

The description of Phase 0 shows how the setting up of infrastructure was made quite visible to senior clinical stakeholders who themselves also contributed to the project infrastructure's strength and form. Rather than being presented as a preformed, coherent, and fixed research method,[10] Phase 0 of VRE could be considered as coherent and flexible—that is, a consultative and collaborative research method. In practice this implies that preparatory work involves an informal transitional process in which we need to learn the cues of professionals and get a sense of their practice: who is doing what, when, and where. During Phase 0 our work is not sanitized in the way published accounts convey (Law 2004; Plows 2018). All our moves—back and forth—are in the open and are on display. Take, for example, our filming—and being advised by participants of where and when to film—in a project on improving clinical handovers in an Australian emergency department (ED).

Vignette: Commencing Video Recording in the ED

In order to film handovers of patients, we first had to find out what time and location the handovers are usually done to be able to capture them on film. We were advised by the ED staff to stand in the middle of the ED's workstation to be on the spot with our camera when handovers happen during the day. However, handover moments, as it turned out, are not always self-evident. In fact, many discreet and informal event-triggered handovers were happening, and we were not always able to recognize them. This resulted in filming colleagues in conversations that we incorrectly identified as handovers. Obviously, we then stopped filming and apologized the moment we realized what was going on. We found ourselves wondering if clinicians were doing a handover, just talking to each other about practical matters, discussing a patient, their Saturday evening plans, or a combination of all of the above. When we did recognize the right handover moment, we were often too late to capture the handover on video. (Adapted from Carroll and Mesman 2011, 162)

Our vignette details how as researchers we were required to learn how to recognize both formal and informal handovers, which was not easy! As we tried to get a sense of their communication practice, they could see us quite literally running around

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with a camera, filming, interrupting, and then quickly apologizing for filming the wrong conversation or missing the right one or being too late. Despite this, we argue that our collaborative production of an infrastructure created through action actually produces solid ground for this type of making & doing research: relationship building comes with a cost—that is, both an exposure of and an inclusion in, our Phase 0 orientation practices of VRE.

Preparatory work for building robustness in VRE research is both methodologically foundational and deeply messy. Given that context and social history define "mess," is mess always messy? Following Douglas (1966), isn't mess just "method-out-of-place"? Or take one more step and follow John Law's (2007) adage of "let's not repress mess." Instead, Law argues, method should be messy, because that is what research is, that is what the world is: complex and messy. Although embarrassment and joyful laughter took turn in our responses to our own trials and errors through mess, it was through these actions that we made ourselves open and ready for unpacking the slippery, noncoherent, fuzzy (medical) world of communication *with* our clinician participants. Yet as we continued to find our way, we dragged more mud onto the carpet (Geary 2018). Let's return to the Australian ED.

Vignette: Donned in Scrubs

We anticipated that we would wear smart-casual street clothes to the hospital. However, one of the key gatekeepers of the operating theater suggested that we should wear the blue theater scrubs that all theater staff wear. This was suggested so that we could easily film the handovers as we followed patient trajectories from the ED to surgery without having to change into theater attire. Indeed, this was a very practical suggestion. So from the first until the last day of videoing, we donned theater scrubs at the start of each shift and entered the ED. The key gatekeeper was correct. We found that wearing theater scrubs assisted our access to the ED. For instance, without scrubs, if we left the ED and then wanted to later return, we had to wait for staff to note and then approve our reentry into the ED. Our scrubs assisted our access because wearing the scrubs alone was reason enough for the ED staff to open the door! By wearing scrubs, we transited from being "outsider" researchers to being legitimate entrants into the ED, therefore diminishing an "us-versus-them" appearance. We also became less "visible" and more official to patients and their families. Our scrubs made patients think we belonged to the hospital staff, and this meant that we made a seamless transition as we joined other staff behind the curtains to hear patients recount their injuries or ills to the ED staff. Thus, in the absence of a video camera or a written or verbal statement of our research project, for the patients we were just one of the many ED staff.

However, we felt that our outer appearance of being insiders was not working at all with our inner selves as ethnographers.[11] We had angst over our not

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having enough time to form genuine relationships with people to begin to be considered as insiders. Although our wearing scrubs assisted us with insider status, we also felt they were a Band-Aid for our lack of time to gain access and build genuine and honest relationships.

Method comes with mess, argues Law (2004, 2007), and we agree happily and, as he does, do not equate a mess with poor research. Producing mess comes in different forms, such as confusion and discomfort that affects everyone involved, including us. But our maneuvering with mess also had the effect of ironing things out and building up trust, which contributed to robustness. For example, our wearing of scrubs also became an opportunity to rearticulate our researcher identity to clinicians who did not know otherwise. Messes, in other words, are ruptures in the organization that offer opportunities for relationship building. When staff from the surgery department, also wearing scrubs, entered the ED they noticed two "colleagues" in scrubs and often gave us a "Hi, you are one of us" look, smile, or nod, but in a split second we moved from being "one of us" to "one of us?" This facilitated the opportune moment to talk about the video handover project and ask for consent in videoing handover moments involving these clinicians. Thus, the simplicity of a full insider or a full outsider status is too great to capture the changing relationships we had with different staff.[12] For us the turbulence created by mess is part of directing a study toward a state of all's well and a state of bonding and embedding but not there yet. Even when we get there and establish trust and a collaboratively built infrastructure on which to begin filming, it continues to be messy, because reality itself is "overwhelming, excessive, energetic, a set of undecided potentialities, and an ultimately undecidable flux" (Law 2004, 144). Our production of robustness suggests that mess may not be disorderly in an ontological and epistemological sense. As method-out-of-place it lives at the same time in relationship with some kind of ordered directionalities that can yield robust ways of doing. Thus, reawareness and reconceptualization could be considered outcomes of making & doing projects that are not limited to participant professionals. We as researcher participants reflexively learn in VRE as a form of making & doing as well. This might seem to be a clear methodological principle, but as we have detailed of our time in the ED, acting as researcher participants can be very confusing and confronting.[13]

MAKING A DIFFERENCE PRODUCES EQUALITY

While producing mess *and* robustness, making & doing may also be accompanied by vulnerability. First, the transparency of foundational activities enables clinicians to see attempts, successes, and mistakes. Yet more importantly, being on location means we are available for direct criticism, praise, and advice from participants (Carroll 2009). The collaborative character on which intervention is based transforms our project

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beyond recognition. Although intervention comes with these kinds of vulnerabilities, they also provide opportunities and gains.

A successful Phase 0 is crucial in order to explain (and explain through doing) VRE's epistemology to stakeholders so that expectations can be managed and VRE can be allotted space within their research traditions or improvement traditions. We have found clinical staff to be very receptive to what they see as qualitative research and understanding that it has a different foundation. This is in part because of the preparatory work that we do in Phase 0, which involves formal meetings and informal talks, presenting to and educating people about what VRE is and what it offers. They quickly learn that you are operating in a different paradigm. In conjunction with building genuine and respectful relationships throughout Phase 0, we have experienced genuine respect for our expertise as professional researchers and have been able to convey our professional respect for participants. In our experience, we have always been taken seriously when doing interventionist research within the realist paradigm of clinical space. The intense collaboration that characterizes making & doing projects like ours provides participants an understanding that bridges differences between paradigms of understanding and reasoning. As participants are slowly turned into coresearchers, messiness becomes constructive adjustment and required flexibility for all involved. It turns out that our professional credibility not so much jeopardizes our making and doing in the open but establishes it as we go about doing our mess in a relationally driven, collaborative, transparent, humble, and therefore trustworthy way.

As we transition from filming to facilitating reflexive sessions, we are not so much outsiders or insiders but alongsiders (Carroll 2009). Our presence is of course no news for STS scholars and colleagues from other fields such as critical anthropology and feminist studies. But the implication of this situation is that participants can hold us accountable right on the spot during reflexive sessions (Carroll 2009). Presenting our findings directly to those we study instead of via a research paper or policy note is explication of our researcher's gaze (Carroll 2009). The researcher's gaze is about framing. This brings in the issue of control of the representation of the practice. In other words, producing images and representing practice is not innocent but an act of power. Participating clinicians sometimes criticize or compliment us on footage we filmed, although that is not an explicit item on the agenda. Reflexive sessions can act as "a period of contemporaneous formal accountability for both clinicians' work practices and also for the researcher's own analysis and framing of clinicians' work" (Carroll 2009, 258).

In our way of making & doing, the professional's practice is discussed and evaluated, and the researcher's work as well. The researcher can be held formally accountable—a process that arguably is more likely to happen when the researcher is present. Thus, such researcher vulnerability that we have described includes the way we make & do. Collaborative research puts us not only in the position of receiving

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critical questions, critique, and compliments but also involves vulnerabilities for our research agenda: When does giving in and being flexible become a threat to one's ambitions? How to keep one's research project from being co-opted by managerial or medical agendas (Mesman 2007; Timmermans 2013)? In other words, how much involvement can VRE as one type of making & doing handle? In our experience, collaboration is not a matter of being submerged or being in full control. It is the common ground that should be the focus of attention.

CONCLUSION

The preceding describes VRE as making & doing that contributes to a reawareness, reappreciation, and reconceptualization of daily practices and can initiate new insights and change for both the professionals and the involved researchers. We also explain how making & doing projects using VRE benefit from STS by opening up practices in a counterintuitive way. In return, making & doing VRE projects offer opportunities for STS knowledge to travel and further develop. VRE, as our way of making & doing, is a passageway for STS knowledge and will continue to be in the future through training of professionals in planned obsolescence and the HELiCS[14] resource (Iedema et al. 2009a). Moreover, instead of pursuing a long trajectory via policy and education, copresent researchers using VRE in making & doing projects can affect practice immediately instead of being distant figures who stand behind reports that contain lists of recommendations. To have an effect requires a robust foundation. Because such rigor emerges and is coproduced on location, mess in method is on full display as "all of us in action." The local character of making & doing VRE projects enables participants to not only see but contribute to our adjustments, successes, and failures. Through this gaze we are rendered just as vulnerable as those we study. The transparency that making & doing brings through the use of VRE has the potential to create discomfort or even suspicion about the quality of the project or our research credentials. Yet, as we discuss, messy collaboration is time intensive *and* relationship building, and it results in the robust foundation that making & doing through VRE not only acts upon but also requires. It contributes to trust as we proceed on the path that "all of us in action" have to walk. Participants intervene in our way of doing, as we do in theirs. This equalizes our vulnerability and is the interventionist principle of symmetry that making & doing VRE projects harbor. In making & doing, it is possible that everyone and everything is made and done.

While opening, pushing, and turning, we are all contaminated. This "artful contamination" (Zuiderent-Jerak and Jensen 2007, 232) has consequences beyond the walls of the practice. For example, although at first sight planned obsolescence seemed a lost cause because VRE is completely taken over by others, we—and for the very same reason—consider it the ultimate success of making a difference, because it leaves a structural mark in the ecology of health care practice. This example indicates

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that we have to be cautious before defining outcomes of collaboration as risks or as success. Moreover, because planned obsolescence does not require the presence of a researcher, there is the rare possibility of a scaling up. Through VRE, making & doing can now travel to other wards in the hospital or to another hospital or even to another kind of practice, like the control room of a railroad company. As VRE becomes widespread, it amplifies our making & doing.

Making & doing through VRE opens up existing practices for both the researcher and the professionals to look at their daily work differently, assisting them in asking new questions, and looking for answers in other corners. Not only practitioners learn. Our engagement with practices also gives us the possibility to learn about and from these practices. While doing this we also learn about ourselves and how our professional biographies affect our ways of doing research (Carroll and Mesman 2011). Writing this chapter caused us to exnovate our Phase 0 practices, which are mundane and have been overlooked and taken for granted. Thus, using VRE as one mode of making & doing provides STS scholars a way into day-to-day practices to reflexively learn about others *and* themselves.

NOTES

1. Several research approaches are aimed at practice optimization while including participants actively in the knowledge production—for example, community-based participatory research, participatory research, participatory action research, and collaborative ethnography.

2. Using "professional" for everyone except the researcher has no normative connotation.

3. For more discussion on these twin goals, see Carroll and Mesman (2018) and Iedema et al. (2019).

4. For an analysis of the implications of the researcher's position for knowledge production, see Carroll and Mesman (2018).

5. Acknowledging the STS contribution to our interventionist research, and to VRE in particular, does not deny the fact that it is hard to define exactly which and to what extent contributions are made. Therefore, we are cautious in attributing aspects solely to STS.

6. The other guiding principles are care, collaboration, and reflexivity (see Iedema et al. 2019).

7. As such, VRE comes close to the method of "situated intervention" as defined by Zuiderent-Jerak (2015, 23).

8. Iedema et al. (2019) is a clear exception to this trend.

9. One may choose clinalyst, affect as method, or planned obsolescence as VRE format.

10. This has been debunked by Law (2012) and Zuiderent-Jerak (2007), among others.

11. For an elaboration of the tension of our ethnographer identity with a rapid VRE project, see Carroll and Mesman (2011).

12. See Mesman (2007) for more on the fluidity of the insider-outsider dichotomy.

13. VRE researchers have explored the importance of the researchers' role in shaping how VRE is used, how relationships with participants are formed, and the type of knowledge that may be generated as a result of certain researcher orientations to the doing of VRE (Carroll 2009; Carroll and Mesman 2011, 2018; Collier and Wyer 2016; Wyer et al. 2017).

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14. HELiCS (Handover—Enabling Learning in Communication for Safety) is a toolkit freely available to health professionals and was developed by VRE researchers in Australia to independently teach VRE for the purposes of learning handover communication. For more information, see Iedema et al. (2009a).

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8

ALTER-ENGINEERED WORLDS

Nicholas Shapiro

In our late-industrial times, two weighty terrestrial infrastructures appear inescapable when attempting to lift off from the earth's surface. Whether it's gasoline in propeller planes, kerosene in jet engines, or propane in hot air balloons, going up isn't possible without drilling down. The actual burning of fuel in commercial airplanes, pumping out innumerable ultrafine particles and fifty pounds of CO_2 for every mile traveled, is the final corrosive sputter of an already environmentally costly hydrocarbon extraction process. Less materially manifest than the mesh of pipelines, condensate tanks, drill rigs, fracking chemical impoundments, water trucks, refineries, and compressor stations that establish landscapes of oil and gas extraction—and are necessary for flight—are a second set of infrastructures, those that maintain intellectual property. Aircraft like the Boeing 787 Dreamliner are the vibrating embodiments of over a thousand patents and many more proprietary secrets (Glickert 2010). Even the dinky puddle jumper in which I am now writing is a colossal manifestation of knowledge enclosure (figure 8.1). These two infrastructures—hydrocarbon extraction and intellectual property—are just two of the many ways that human technical systems, knowledge practices, law, and human-environmental relations collectively buttress the corrosive status quo. In this chapter I confine myself to these two dominant ways of making and doing to ask: How might STS scholars and allies differently engineer the hydrocarbon and intellectual property infrastructures that envelop our world? Or, more precisely, how might bricolages of science and technology researchers and practitioners differently foster worlds in which hydrocarbon extraction is no longer an engineering problem to be infinitely tweaked and optimized, but a quest that becomes abandoned in an altogether different relationship with energy?[1]

What I'm trundling toward, with a motley crew of collaborators, does not include the dominant climate solutions that seek to eke electricity out of the sun, wind, and waves. In my mind, decarbonizing the grid is not an answer to these questions. The

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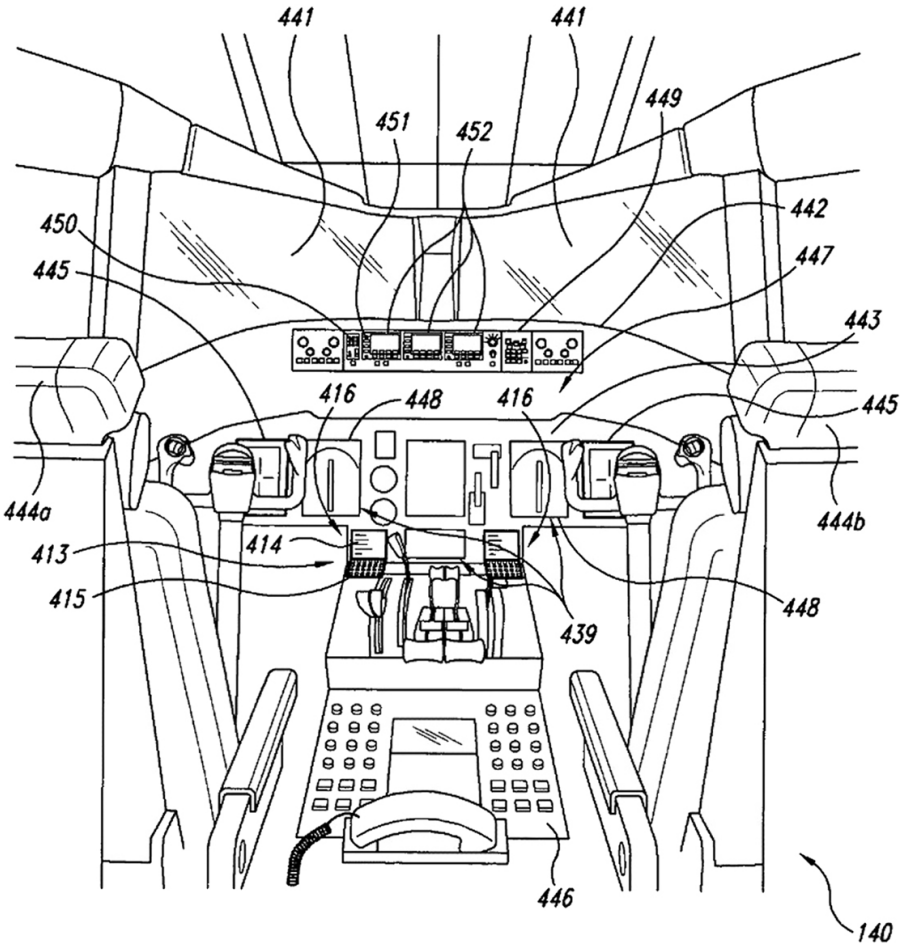

8.1 Image from US Patent No. 7,177,731.

world that has been built around fossil fuel extraction will not veer into benevolence by, for example, plugging our current infrastructures for energy production and consumption into a different source. The problem of hydrocarbons does not end with hydrocarbons because, as Matthew Huber has argued, "Oil is better understood as a social relation"; it is a product of both "the materiality of petroleum and the social projects that channel its biophysical capacities in particular ways" (2013, 4). Decarbonizing the grid without grappling with the assumptions, imaginaries, extractive logics, asymmetrical financial benefits, regimes of consumption, and traditions of ecological mastery that were honed in tandem with hydrocarbon engineering allows these social practices and infrastructures to churn on with new "green" lifeblood. If only the material and not its social relations are terminated, the problems of oil are not solved.

The quest for energy efficiency, an imperative that is allied with decarbonization, often seeks to make the harms of our engineered worlds bearable enough to evade more

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fundamental abandonment (see Date and Chandrasekharan 2017). A decade ago a friend of the critical theorist Eyal Weizman joked to him that a large sculpture of the number 665 should be erected as a monument to the dominant calculative political credo of the lesser evil, which pragmatically notes that there *are* necessary violences that are both unavoidable and able to be moderated (Weizman 2011). Just one imaginary unit of harm away from the undeniable wrongness of 666. And indeed, from carbon austerity to toxics reform, this is where our dominant environmentalism lives; 665, or the maximum allowable harm, represents the optimal operating emissions level of industrial infrastructure and the basis of permission-to-pollute regulations. Although what counts as just shy of the number of the beast changes over time and space, activists and titans of industry often come down on the same side in terms of supporting the framing logic of necessary harm mitigation. Small wins and well-meaning regulations that emerge within sanctioned adversarial arenas of contestation further root both toxic emissions and their social projects in the future (Shapiro 2019). Making harms *un*necessary is unimaginable within this commanding logic. The lesser evil, and the regimes of urgency that support it, renders refusing its triage beyond the pale of the feasible and reasonable, making robust alternatives easily dismissible (Whyte 2012, 67).

The electric vehicle is a perfect embodiment of lesser-evil-style change that is designed to grant sameness. A change that perpetuates the environmental relations and consumer culture that the car has come to represent while displacing the issue of energy generation to elsewhere in the grid. Electric vehicles and the some ten million miles of ecosystem-segmenting, hydrology-altering, ossified oil spills that are roadways mutually constitute each other. The point here is to note what gets entrenched when the horizons of environmental possibility are circumscribed by lesser-evil logics.[2]

This world is not a product of hydrocarbons in and of themselves but a product of a mode of relating to each other and the extra-human environment that they helped advance and, in advancing, also helped constitute. There is no one headwater to these modes of relation but a set of tributaries that braid together in mutual reinforcement. No need to name your alliance in the ongoing -opocene debates (capitalocene, plantationocene, Anthropocene, cluthocene, coloniocene, and so on), because they all offer crucial and partial insights. Even *if* we were able to hone our critical analytic vision of these multivariate violences that differently entangle across locales, regions, and continents, transforming that critique into an alternative practice remains tricky business. This is indeed one of the dilemmas of the hybrid practices of this volume—how do our critiques relate to our attempts to make and do the world differently? Turning critiques directly into action can be absolutely necessary, as in anticolonial rebellions, but they can also lead to more puzzling problem spaces when adversarial contentions succeed yet might not articulate a world that the resistance does in fact want. Indigenous critiques of the Anthropocene concept and mainstream climate justice stand apart from this dilemma of critique without

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paradigmatically different alternatives. Indigenous researchers not only articulate exacting genealogies of violence and recenter ongoing projects of (settler) colonialism as equal and coconstituting forces alongside climate change and industrial pollution but also carry and advance robust traditions of environmental stewardship, accountability, and protocols for being in good more-than-human relations (Estes 2019; LaDuke 1999; Liboiron 2017; Simmons 2017; Simpson 2017).

The "alter-" of the title of this chapter does not turn its back on the vital movements that arise in denunciation to oppressive infrastructures, institutions, and relations but wonders if enacting alternatives may be a means of denunciation through affirmation of an otherwise (see Hage 2015). In other words, alter-engineering is saying no by saying yes to practices that the norm makes unimaginable.[3] Alter-engineering is not simply de-engineering. It is not bolt-by-bolt dismantling the most egregious modes of pollution until we have optimized our own global despoilment. It seeks intervention into what presuppositions compose the frame of the problem to be solved. If the problem is a set of norms and not how much of chemical x is emitted by process y, then the intervention is not limited to the calculative logistics of reformism that often lead to a perpetually *just*-out-of-reach flourishing. Pursuing ever-thickening documentation of chemical harms remains vitally important in the short term, but limiting both the conceptualization of the problem and the subsequent action to specific chemicals in specific places often lands communities and researcher allies on a path to justice that takes the form of a data treadmill (Shapiro, Zakariya, and Roberts 2017). Even if, and this is a tragically extensive if, chemical harms are able to be evinced and catch traction, such data are often used to refine process of exposure, insulating against further or more substantial overhaul and leading more to entrenchment than resolution.

A half century ago, Buckminster Fuller urged a sentiment akin to alter-engineering, aiming to pivot from directly contesting the existing reality to indirectly cultivating an alternative model that renders prevailing norms obsolete. Yet most of his work took the mantle of increasing industrial efficiency as the optimal means of conjuring obsolescence. How might the crises of today—dilating awareness of the cruelty of optimism (Berlant 2011) related to big data, industrialism, and innovation, for example—differently inflect our vision of what otherwise-engineered systems might look like? How might critical practitioners establish a destination for environmentalist dreams that bristle with critique of the present but are rightfully weary of roosting among the viable futures touted by industry, reformists, and technocrats?

By no means is alter-engineering attempting to envision engineering without engineers. Any system that relies on the likes of me to ensure its physical integrity is not a system I want to rely on. What I'm suggesting is that the various expertises of engineering could be augmented by historical and anthropological insights of STS to collaborate on problem setting, to be open to the possibility of multiple incommensurable solutions, and iterating on the values and assumptions that are

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used to address problems. Inspired by STS work attempting to alter the trajectory of engineering education (Fortun et al. 2014; see also Downey, chapter 10 in this volume), I sketch out what alter-engineering might look like though a collaborative project that, in my mind, fosters these alternative approaches to wielding the traditional tools of engineering. The project, like any other, is no silver bullet but begins to work through how to live differently in an age of uneven environmental destruction.

ENGINEERING ETHOS: TOWARD CALCULATED SUBMISSION

From jet engines to hot air balloon burners, long-distance travel is hard to imagine without combustion. Given the tremendous weight of batteries, the go-to lesser-evil approach of electrification isn't an option for long-distance travel. Solar planes are merely toys for aging stuntmen as they cruise at 30 mph and require a control room full of meteorologists to find the right paths for their flimsy wings. In thinking about flight, let us then consider the stratospheric balloon as a seemingly innocuous form of air travel. These balloons gain their buoyancy though helium's low weight and propel the sensors that give us much of the detail in our weather forecasting. Helium-rich natural gas is, and has always been, the only source of commercially available helium. Although not itself a greenhouse gas or toxic to biotic life, helium is directly implicated in the vast infrastructure for extracting natural gas (i.e., methane). For balloons filled with helium to gently ascend into the atmosphere, we also need the drilling capacities and pipeline systems of a world hungry for natural gas. During the extraction and transportation of natural gas, methane—some thirty-two times more potent a greenhouse gas than CO_2—is routinely released, vented, and leaked into the atmosphere. These emissions amount to the largest source of methane release in the United States and are necessary to produce that most noble of gases, helium.[4]

The extractive infrastructures of helium are not limited to what industry and regulators consider to be infrastructure. We must also include slow valve leaks, permitted airborne emissions, fragmented habitats from millions of miles of pipeline, and the alarming effects of endocrine disruptors released in the wresting and refining process as fundamental aspects of the natural gas–cum-helium infrastructure. These regular excesses are precisely what Michelle Murphy has referred to as "chemical infrastructures that materially and unevenly shape human and non-human life in time and space" (2013). It is because "abnormal operating conditions" are the status quo that recent data indicate that methane leaks are 60% higher than estimates of the US Environmental Protection Agency (Alvarez et al. 2018, 168). The inclusion of fugitive—and sometimes insensible—chemicals into our understanding of infrastructure is not a mere provocation. It is an acknowledgment, long past due, of the chemically suffused and sculpted nature of life in our contemporary moment.

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But what is more fundamentally past due than a more robust accounting of extractive infrastructures is the recognition of other unseen but much more ancient earthly infrastructures. One such project, which I have had the luck of working with for the past few years, attempts to intervene in hydrocarbon exposures and carbon emissions not through the traditional avenue of documenting harms and demanding policy change but by attempting to cultivate dreamworlds that do not run on the technological domination of natural resources. The project is led by the Argentine, but now Berlin-based, artist Tomás Saraceno and seeks to realize aerosolar balloon travel as a viable means of global mobility. Aerosolar aircraft are simply large envelopes that are heated by the sun and move with the wind. As opposed to aerodynamic force that holds aloft planes and helicopters, the aerostatic lift of these balloons does not require concentrated forms of energy to create relative motion over an airfoil (a wing or propeller blade). Rather, the soft architecture of these aerostats becomes buoyant by the expansion of the solar-heated air within it.

Without need to convert solar rays to electricity, these aircraft buck the gridded assumptions of conventional environmental alternatives that are weighty with needs for mined metals, batteries that need to be replaced every six years, and massive amounts of energy lost in transmission. Although aerosolar balloons do not require batteries, they are not free of the need for energy to keep them aloft after the sun sets. On multiday flights they remain aloft at night because they are designed to use the infrared radiation that the earth returns to the cosmos at night (think of a piping-hot sidewalk at midnight in the summer). Instead of disposable energy reserves small enough to be portable (batteries), the project thinks on a cosmic scale with our planet itself functioning as an omnipresent source of reserve energy after the sun has set. The shelf life of this means of nocturnal buoyancy is approximately five billion years, or until our sun begins to die. In the thermodynamics of this project, the battery finds its obsolescence deep in the past, before life on earth began.

The project begins by attuning to and moving with the forces that animate our planet. Conceiving of wind and solar rays as critical infrastructures for the ongoing present demands that our desires be reengineered through forgotten supply chains: the planet's shared and circulating atmosphere. These currents of interest are not merely the aerial flows that propelled a nautical yesteryear but multiple, overlapping, dynamic, and sometimes countercurrent atmospheric strata that have only recently become modelable in their full complexity. If you were to look up from this page and levitate vertically from your chair up through the air column, you would encounter many different wind directions and velocities as you traveled through the roughly ten miles of navigable atmosphere up into the upper stratosphere (figure 8.2). With different directional and speed opportunities at different altitudes, adjusting one's altitude becomes a way of steering an otherwise haphazard trajectory.

Collaborators at MIT's Earth, Atmospheric, and Planetary Sciences department have developed a web platform for atmospheric imagination (https://floatpredictor

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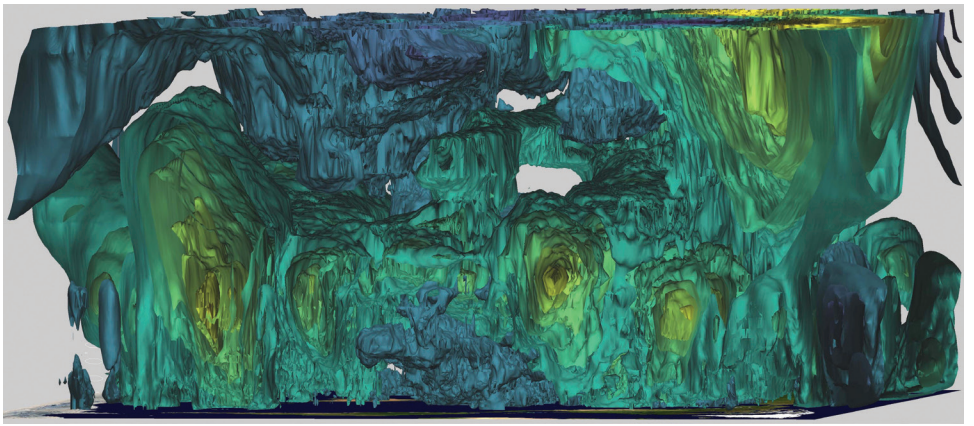

8.2 A 3D vertical slice of winds; blue and yellow indicate winds flowing in opposite directions. Image by Bill McKenna, MIT Earth, Atmospheric, and Planetary Sciences.

.aerocene.org/) that enables you to know when to fly and at what altitudes in order to string together the right winds and reach a destination of your choosing. Just as you can select flexible dates in an airline marketplace to find the cheapest ticket, you can note that your dates are flexible to find out which winds on which days will get you closest to your destination. The platform uses public data from the Global Forecast System—maintained by the US National Weather Service—to model the flight trajectories. The platform seeks to make mass aerosolar travel imaginable, a first step in large-scale adoption. Such an engagement with both the elements and big data evinces a project with a complex orientation: both of and beyond this world.[5] The theory of change of this project is not the empirical dream of critiquing an existing problem into oblivion but the realization of the transit infrastructure latent in the complexities of our everyday ecology. This approach to change also evinces a foundational ethos for a mode of alter-engineering that does not attempt to overcome or interrupt nature in an eternal quest for mastery and comfort but attempts to realize a human relationship with the environment that is predicated on calculated submission. In the project, the ethos of calculated submission—of using cutting-edge tools and data but to move *with* the elements rather than overpower them (Engelmann and McCormack 2018)—as an engineering principle is not didactically handed down as a bullet point on a PowerPoint slide. Rather, this sensibility emerges and continuously reemerges through framing the problem not as how can we travel with as little fuel as possible, or with biofuels that reduce extraction impacts, but as what are the alternative thermodynamics that could make long distance and high speed (jet streams regularly reach speeds of hundreds of miles an hour) possible.

The project, dubbed the Aerocene, is informed by the sometimes-competing genealogies that mark the -opocene debates. It does not, however, assert lineages of harm causation but conjures slippery temporalities and possibilities of environmental

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harm preemption, of pasts becoming future and of futures becoming present. The vision of this project is not undergirded by restorative nostalgia for a romanticized nontechnological past (like that offered by anarcho primitivism). If any, the project draws on a reflective nostalgia (Dlamini 2009) that pulls centuries-old technologies, cutting-edge science, and the fabulations of science fiction into the same frame. Because balloons were already wistful novelties during the nineteenth century and solar balloons have not yet been fully realized for flight, tense (past perfect, future anterior, and so on) begins breaking loose when trying to locate the Aerocene. It is a chronotrope without the golden spikes of terrestrial eras (golden spikes are geological markers that are used to indicate the transition between epochs, ages, and eras), one whose movement is already enjoyed by the fungal, avian, insect, and bacterial species that regularly cruise on atmospheric currents. Humans are only now warming to its promise and rising to its challenge.

The project involves an ever-increasing array of collaborators: from architects and aerospace engineers designing the balloons to electrical engineers designing the circuit boards of the positioning and data relay systems, sound artists experimenting with infrasound sensors on board, atmospheric scientists modeling the elemental variables of flight, physicists calculating solar flux, community organizers hoping to encourage public participation, and a gaggle of STS scholars: Sasha Engelmann, Bronislaw Szerszynski, Derek McCormack, and me. Reviewers have duly asked me to detail what exactly I've made and done within this project. My role, like that of everyone else, is multiple and ill defined. At times, parsing one's individual contributions to a project like this can feel out of touch and self-interested, because all aspects of the work are brought into being by many hands. At other times, it feels absolutely necessary because volunteer labor can be made invisible in a project of this scale and tacitly credited to the most prominent figures involved. The need for generous attribution is likely inversely correlated with eminence, although much of the world works on an opposite model.

In my contributions, I led the solar balloon launch in Antarctica, demonstrating how well the balloons work in remote, resource-scarce regions, and in Idaho during the 2017 solar eclipse to assess the effect of the eclipse on balloon internal temperature and altitude. I've attempted to hawk the idea to funders and politicians at the World Economic Forum. I've supplied and advised on how and what air quality sensors might be best suspended from the balloon (the only one I supplied was destroyed when the chase team stepped on it during recovery) to test its ability to perform atmospheric monitoring. I, along with Liz Barry, developed a lending library model and data-sharing protocol to be used in five provinces in Argentina. I've helped transition the project's hardware to open licensing and advised on what organizational structure would be best suited to develop the community, hardware, and software. Occasionally I write small pieces for exhibitions and symposia, and indeed this chapter, and

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its at times uncomfortably declarative voice, grew out of an essay that was originally circulated at the Solutions COP21 conference (the 2015 Paris Climate Conference). But perhaps most of all, I've been speaking publicly about the project, bringing my experiences in environmental justice work and my frustrations with the dominant avenues of detoxification into relation with what a project like this has to offer. My argument in those talks, and in this and related essays, is that paradigm-shifting projects like this have serious environmental justice chops, just in an extremely long-term timescale that is often triaged out in conventional approaches.

In this work I, and many, many others, shift back and forth between writing and speaking social scientifically, participating in scientific experiments, calibrating visions of living differently to the possibilities and limitations of physics, and the often hidden work needed to hold groups of people together. Polyglot working practices result from collaborators continually cross-training each other. That the project is led by an artist likely facilitates interdisciplinarity because no mode of knowing and imagining is prioritized. At the same time, some members and supporters of the project can get frustrated when developing infrastructure, technology, and community take a backseat to communicating the potentiality of the idea in art exhibitions. As is often the case, disparities in revenue sources undergird where the most follow-through can be directed. Establishing a research and development grantmaking capacity may help even out priorities.

MIXING THE FLAVORS OF INCREMENTALISM AND RADICAL ALTERITY

The Aerocene does not entail becoming the wind and turning one's back on terra firma, although its global scale does, at times, leave it ungrounded.[6] In many ways the project is no more, and possibly less, of an escapist fantasy than the constrained pragmatism of technocratic reformism (Shapiro 2019; Shapiro, Zakariya, and Roberts 2017). Instead, attempting to realize a world organized around the calculated submission of solar balloon travel engages our besmirched earth, the toxic chemical infrastructures that suffuse life, and the corrosive happenings that condition both biotic and geologic beings. It attempts to do this in multiple ways and varying degrees of success.

One of the reasons I was invited to collaborate on this project is because of my work developing low-cost air quality monitors (e.g., Zhang et al. 2019) with the grassroots environmental monitoring nonprofit Public Lab. My task was to think about how—during these first fledgling days of the Aerocene, when human aerosolar travel is decades away—these aircraft could be equipped with the instruments to monitor the earth's current chemical infrastructures. In workshops and chance meetings from coastal Louisiana to the Solomon Islands, people have variously proposed attaching sensors to these balloons to monitor stratospheric ozone levels, measure tropospheric particulate matter levels, trawl the oceans for microplastics, assess methane

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releases from pipelines, track ocean acidification, launch weather balloons in inaccessible areas, disperse seeds over rugged forest fire–scorched earth, log the flux of high aerial bacteria and fungi, or enumerate shale-field flares. The hope is that these balloons, which aim to supplant global infrastructures of fossil fuel–based travel in the long term, can be leveraged to advance hyperlocal environmental engagement and knowledge production in the short term. In other words, the aspiration is that the technologies of a radical alternative can also serve as a vessel for instrumental incremental change.

That the project feels compelled to prove its value by aligning itself with established modes of justice and conservation is illuminating of the monopoly technocratic reformism holds on how we imagine the future. There are without doubt frictions between these logics, but how incommensurable are the utopic and the lesser-evil approaches?

The brainstormed applications mentioned earlier could be categorized as "civic technoscience" (Wylie et al. 2014) that aims to pluralize how and who can make authoritative claims about the environment. This nascent technological practice shares values with the Aerocene project, which similarly hopes to expand how and who can fly and with what ecological cost. Both attempts to make low-cost environmental sensors and low-cost aerosolar aircraft (you can make a *very dangerous* human-carrying aerosolar balloon with $200 of materials, two people, and simple pictographic instructions) seek to make simplicity and price point inroads to accessing rarified tools and capacities. Attempting to make solar balloons into platforms for environmental auditing and controlled environmental observation quickly encounters pragmatic shortcomings. Because solar balloon trajectories are constantly in flux, as they are the upshot of multiple shifting elemental phenomena, they almost never take exactly the same flight twice. Akin to Natasha Myers's "ungird-able ecologies" that refuse the "norms and logics of conventional ecology" (Myers 2017, 11), these unrepeatable flights, at cruising altitudes tens of thousands of feet above the surface of the earth, bear little capacity to adjudicate toxic emissions spouting from even the tallest smokestack. These balloons perform reformist science badly because their routes are coproduced by human desires and elemental forces. The pragmatic incommensurability between these two practices of technoscience and environmental change reinforces my working assumption that the path of documenting harms and violences does not lead to paradigmatically different modes of "ethical doings in naturecultures" (Puig de la Bellacasa 2010).

For these reasons, I continually wriggle out of my impossible charge to discern what scientific payloads would be most useful to environmental justice advocates. Rather than function as a platform for civic technoscience, the well-publicized quasi-plausible future that the project advocates for is perhaps most relevant as simply a platform. Joaquín Ezcurra, a staff member at the Aerocene Foundation,

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which supports the project, has been working with Débora Swistun and other community members of Inflamable, a shantytown situated next to a sprawling petrochemical complex outside Buenos Aires. The Aerocene, which routinely is featured in international media, serves as a platform pressuring the state to reckon with the ongoing chemical violence wrought on the town through erecting fifteen-foot-high images of the polluting facility in a Paris exhibition, ensuring that Swistun was one of the first people lifted by the balloon, and using tethered solar balloons as rallying points for protests. These are extremely humble and emergent ways that the project *might* bear some impact before the unknown date of its realization at scale.

The mutual exclusivity of lesser-evil and radical-alterity approaches does not prevent them from being mutually interdependent. They have different logics of change and obligations to different presents and futures that are insufficient on their own. Neither is superior, but I am left with an intense appreciation of the labor needed to carve out imaginative space beyond polishing the status quo. The tension I'm pointing to is a productive friction and one that calls for syncretic methods of environmental change. Struggles with the technicalities of getting sensors that yield environmental justice–relevant data aloft on these utopic balloons is what pushed me to better grapple with the perils and potentials of both approaches to attempting to live ethically alongside durative toxic infrastructure.

OWNING (THE) MOVEMENT

Sublimating into the Aerocene cannot be done using the same methods that constructed our current state of becoming. Placing Aerocene designs in the creative commons is a small step toward giving rise to alternative flows of knowledge, circulation of capital, transparency of research, and an idea of property that runs in partial opposition to European regimes of individual white property ownership that constitute and dominate the settler colonial present (Bhandar 2018; Moreton-Robinson 2015). As the Open Source Hardware Statement of Principles outlines, the bottlenecks in making material technologies truly open, easily modifiable, and adaptable to divergent contexts are not limited to licensing: "Open source hardware uses readily-available components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware" (Open Source Hardware Association, n.d.).[7] Making and doing the world differently requires detailed attention not just to the licensing of final products but also to accessible processes of development.

Returning to stratospheric balloons as the most seemingly innocuous mode of a current type of flight, let's take Google's Project Loon as an example. The project involves flying a large number of stratospheric helium balloons across the Southern

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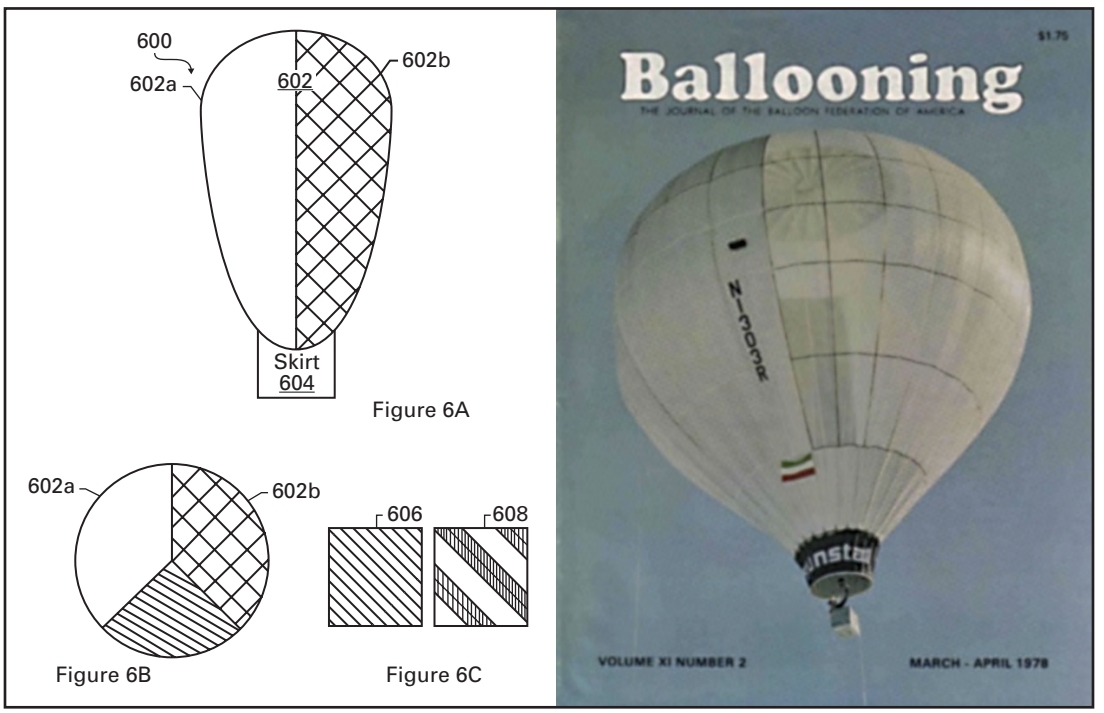
Hemisphere to broadcast LTE internet connections to otherwise offline communities. Sri Lanka may well achieve universal internet coverage via Loon by the time this book goes to print—expanding the Google user base without having to invest in terrestrial infrastructure. The project has tallied some two hundred patents, which tech pundits read as a sign of its imminent success. Loon has created its own automated balloon-manufacturing facility. Balloons that initially lasted only a few hours in the air now stay aloft in the upper layers of the atmosphere for more than a hundred days. But the steps to exponentially increase the life of these balloons remain stuck behind the enclosures of corporate secrecy. Their production process requires specialized machines and vast amounts of capital. Beautifully simple innovations such as Google's Patent No. 20,140,252,163 (from 2012), which rotates darker or lighter sides of the balloon toward the sun to increase or decrease elevation and catch winds of different directions, will remain legally out of reach to aspiring aeronauts for the next two decades. Even more troubling is that a similar, and perhaps more advanced, design of this kind was featured in *Ballooning: Journal of the Balloon Federation of America* in 1978 (Brown 1978) (figure 8.3). Patents can enclose preexisting knowledge, not just safeguard hard-fought and capital-intensive developments.

But even if the Aerocene project were to follow every word of the Open Source Hardware Statement of Principles in the development of our technology, open



8.3 Image from US Patent No. 20,140,252,163 and of a 1978 cover of *Ballooning: Journal of the Balloon Federation of America*.

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licensing can, as Dawn Nafus astutely remarked in her review of this chapter, "feed the beast." For example, open-source code and data practices in universities are the foundation on which large corporations like Amazon are building computer vision-based surveillance systems. Similarly, Jenny Reardon questions the lionizing of openness as an end in itself, especially in the context of the life sciences where its calls have moved from the fringes to being a central and driving force. She asks, "Might the embrace of openness unwittingly install scale and efficiency as the driving imperatives of genomics, displacing the broader goal of building a genomics that is of, for and by the people?" (2017, 168). Open hardware has seen less industry co-optation than both open data and code, but the message is clear: openness alone does not simply confer liberatory politics. But if the hardware that helps realize worlds that do not hinge on hydrocarbon thermodynamics is built from inexpensive, readily available components and materials and via standard processes that do not require massive capital outlays, a resistance to significant co-optation is baked into the very bones of the plans.

In this chapter I offer just a small glimpse of the scaffolding that supports germinal collective dreaming that orients toward alternative worlds. Despite the many preceding caveats about open development, the Aerocene can potentially multiply both those who can contribute to the project and those who can directly benefit from it. These are small steps toward bucking the assumption of industrial capitalism, from geoengineering to electric cars—namely, that the practices and infrastructures that beckoned our present environmental crises can also get us out of it.

The question that opened this chapter, of how to differently engineer the world to make hydrocarbon extraction unnecessary, is by no means now closed by the possibility of the Aerocene. In no way does this work establish a singular destination for environmentalist dreams. Rather, what this chapter renders is one possibility for how to begin reformulating our relationships with the extra-human environment in the long term. In my eyes, what is made and done in the Aerocene project is not the development of a technology but the championing of a different ethos, altered subjectivity, and desires realizable only through the yielding of calculated submission. These immaterial outputs have the opportunity to scale far beyond the balloon itself. Working toward a dramatic realignment of the way we build, move, and relate is not more noble than attempts to remediate and reform in the short term. That practices of reformist science hang awkwardly on the Aerocene is no surprise, because the two have countervailing logics and timescales for change. Overlooking present suffering, inequity, and violence in the pursuit of an alter-engineered future is as unethical as abdicating the future to the dominant trajectories of environmental change. My point here is not to denigrate incremental improvement and divert all energy to extra-ideological attempts at radical technosocial change but to kindle their friction into the warm glow of work that recognizes the mutual value and mutual necessity without collapsing their differences.

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ACKNOWLEDGMENTS

I would like to thank Mathew Lippincott, who provided invaluable research assistance in the preparation of this chapter. Thanks also to Roger Eardley-Pryor, who kindly provided feedback on an ancestral version of this chapter, and Teun Zuiderent-Jerak, Gary Downey, Dawn Nafus, and Kim Fortun for helping to pull the final version into shape. The core of this chapter was originally circulated during the COP21 Solutions conference in Paris in 2015 (see https://aerocene.org/newspaper-shapiro/). In revising this chapter I've wondered if it was indeed even possible to salvage the hybrid art and innovation genre of writing (both poetically mystifying and declarative) for academic contexts. Thanks to Tomás Saraceno and my many collaborators at the Aerocene Foundation and Public Lab, particularly Liz Barry. The chapter and its title are indebted to the collaborative insights of those involved in the Engineered Worlds symposia convened by Joseph Masco, in collaboration with Tim Choy, Jake Kosek, and Michelle Murphy. See https://neubauercollegium.uchicago.edu/events/uc/engineered_worlds/.

NOTES

1. The question of hydrocarbon infrastructures is the primary question in this chapter. As a result, I have to admit that the question of intellectual property will remain somewhat tokenized but will hopefully gesture both to *how* alternative engineering practices are enacted and to the immaterial infrastructures that are mutually constitutive with material infrastructures, avoiding a facile material fetishism.

2. An aside: Because of the increased weight of electric vehicles from hefty batteries, they require more roadway maintenance. Resuspension of particles and tire and road abrasion are intrinsic to automobility. As one modeling study noted, "Fleet electrification has a limited impact on PM_{10} reductions in terms of both emissions (3–4%) and air quality (2–5%)" (Soret, Guevara, and Baldasano 2014, 62). One could also think of what social and material relations of hydrocarbon worlds are maintained in a world fueled by solar panels. Think of the quartz mines, the highly energy intensive (and very often highly toxic) process to produce solar-grade silicon, the 6.9 million gallons of water used annually to clean utility-scale solar installations (or the 400 million gallons used during construction) (Mulvaney 2014), the sensitive desert ecosystems that are increasingly made into wasteland (Voyles 2015) by large arrays, and the operational use of toxicants in dust suppressants, rust inhibitors, antifreeze agents, and herbicides (Hernandez et al. 2014). Think of the demand for cobalt that would quadruple if the world's electricity and transportation infrastructures ran entirely on renewables, most of which is mined in the Democratic Republic of the Congo and implicated in child labor, human rights abuses, and poor worker rights and conditions (Dominish, Florin, and Teske 2019). This is, of course, just a gloss, but it indicates the limits of the cleaner-than-now mode of justification. Think of these issues and it becomes clear that the solar grid (see Ganzeer's forthcoming graphic novel *The Solar Grid* (2022) for an instructive satire) is not in fact a paradigm shift but a technique of salvage.

3. There is perhaps an uncomfortable resonance between this mode of contestation and the workings of biopower whereby power is exercised not through suppression but by mobilizing desires and pleasures.

4. Predecessors to helium balloons were no less implicated. Nineteenth- and early twentieth-century balloons were almost universally filled with coal gas, which is a mixture of hydrogen,

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methane, and carbon monoxide. See U.S. Energy Information Administration (2011) for more information on methane emissions in the United States.

5. This attempt to understand this mode of flight as both *of* the contemporary moment (because it uses materials made with high-grade, hydrocarbon-derived synthetic fabrics) and *beyond* it is in conversation with Michelle Murphy's work that is "both with and against" contemporary forms of technoscience (2017).

6. The project has worked with communities on six continents in the last few years. In a project of this sort it's hard to know how to oscillate between working toward generalizable tools and sustaining work in the particularities of place and community.

7. Open Source Hardware Association (n.d.). See Liboiron et al. (2017) for why equity-based labor acknowledgment is a key practice for knowledge production beyond licensing (and a protocol for enacting those practices).

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9

STS AS A THIRD SPACE BETWEEN EVIDENCE-BASED MEDICINE AND THE HUMAN SCIENCES

Teun Zuiderent-Jerak

We should seek our instruction neither from science alone, nor the sacred, nor any singular form of understanding, but should rather seek to occupy the spaces of transformation which lie between—neither one nor the other but the "third space." Hence Serres (1991) gives the name "third-instructed" (*tiers-instruit*) to him or her who is able to give up the comforts of disciplinary specialism and risk putting themselves into perpetual translation. (Brown 2002, 12)

If you are inspired by this quote, which I of course hope you are, let me alert you that a "third space" between disciplines isn't so much something one can simply occupy at will. *Seeking* to occupy it comes with its histories; histories of individual scholars but also of relationships between fields. Equally, "giv[ing] up the comforts of disciplinary specialism" is not something one can simply decide to do. As far as this quote provides inspiration, it does so for the long haul. As Michel Serres (1983) proposes, seeking to occupy the third space is best imagined as traveling the Northwest Passage, which he, drawing on the messy coastlines in northern Canada that connect the Atlantic and Pacific Oceans, uses as a metaphor for the division between so-called natural and human sciences. As Serres suggests, "The passage resembles a jagged shore, sprinkled with ice, and variable. . . . It's more fractal than truly simple. Less a juncture under control than an adventure to be had" (1995, 70).[1] This demo account is about how to navigate the Northwest Passage[2] and how to make sure critique from the shore does not render its straits impassable. I argue that STS scholarship may be particularly well positioned for such travel, provided it is ready to be transformed by the journey. "Spaces of transformation" are not about impact; they are about being translated. About becoming something that is neither the same nor different from what you currently are. Sounds esoteric. It can happen by email.

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1. INTRODUCTION: A GUIDELINE DEVELOPER'S INVITATION

Find enclosed the info for the abstracts for G-I-N 2011 [conference].[3] We'd like to submit an abstract with you on the safety study.[4] They don't mention safety norms in the call, so we have to find a nice heading to slot it under, or we broaden up the abstract based on the final report on Diversity in Guidelines.[5] Teun, let's talk about this when we see each other next week.

Not an irregular email for an academic to receive. But it was the first time I had gotten such a message from the secretary of a funding agency, and I was excited to receive it. It came from the secretary of the Dutch Council for Quality of Healthcare, a temporary policy agency that was formed in 2009 to commission research as input for setting up the National Health Care Institute (in Dutch, Zorginstituut Nederland, or its predecessor, het Kwaliteitsinstituut), which was to play a major role in the regulation of Dutch health care. The council had been including the Erasmus School of Health Policy and Management, my employer at the time, in top-down tenders because the school is one of the leading players in the Netherlands on health policy research. But developing the studies of the tenders we won was helped much by the fact that this secretary was a former graduate student from the school; the kind of theoretically informed empirical work we delivered was familiar to her. Fortunately, it also resonated well with the remaining leadership of the council, who wanted a broad knowledge base for setting up the institute. Submitting an abstract together was a way to extend and deepen the relationship and, I hoped, strengthen the connection between our claim in a report and the ongoing policy development for the new regulatory agency. That claim—that considering guidelines as regulatory documents for setting *minimum* quality and safety norms or as quality improvement instruments for *complex issues* draws upon two different modes of safety (Jerak-Zuiderent 2012), which require profoundly different knowledges, roles of professionals and regulators, and regulatory ecologies—was a message we wanted to learn to convey. Working on a conference presentation together could thus be an interesting experience for all of us. Moreover, the secretary was a well-known member of the Guidelines International Network (GIN), understanding its conference and abstract conventions as well as being able to provide a clearer sense of how we could best present the study for an international guideline development audience.

All in all, this seemed an interesting way to extend and deepen the connection to guideline development practices that I had been pursuing since completing my dissertation on experimental interventions with standardization of hospital care (Zuiderent-Jerak 2007). In that work I tried, inspired by the work of my PhD supervisor and colleagues (Timmermans and Berg 2003), to bypass sociological work that criticizes the reductionism of standardization by reifying complexity. Through collaboration in projects, Marc Berg, Roland Bal, and I developed an approach[6] that I would later call situated standardization, which consists of organizational experiments that

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empirically elucidate specific issues in health care delivery to help situate standardization attempts in those issues (Zuiderent-Jerak 2015, 72). This approach seemed to speak to guideline development too; a field that in the 1990s developed from a dominance of consensus statements, in which experts agreed, on the basis of their experience, on the weight of different forms of knowledge, to a dominance of epidemiological evidence-appraisal methods, with topic expertise and deliberation coming into the picture only after the epidemiological evidence searches and summaries were done.[7] This development was often referred to as a move from eminence-based to evidence-based medicine (EBM), a move that was heavily criticized from within and outside medicine for being reductionist. But STS colleagues like Tiago Moreira (2005) had painted a more nuanced picture by studying how guideline developers mobilize different repertoires of evaluation when formulating guidance. Moreira showed that guideline developers, rather than being reductionist, include a much wider and more sensible range of considerations in addition to their appraisal of the robustness of scientific evidence from systematic reviews of randomized controlled trials (RCTs) when formulating recommendations.

I had also been following the work of STS scholar Loes Knaapen (2013), who was doing pioneering research on how guideline developers search, appraise, and compose knowledge when formulating recommendations. She had also helped highlight possibilities for including patient knowledge in guidelines through her membership in the GIN Working Group on Patient and Public Involvement. I knew she would be at that GIN 2011 conference too and could (and would!) prove an enormous help in introducing me to participants and active GIN members whom she, through her interviews and committee work, had gotten to know so well.

Moreira's articles and Knaapen's scholarship and professional relations, plus the conversations I had had with them and related scholars over the years, supported my impression that the invitation by the Dutch Council for Quality of Healthcare reflected an openness among guideline developers to empiricize and experiment with their standardization practices. Some colleagues, most notably a professor of political science at my university, thought I was being naïve for accepting the invitation; a senior STS colleague told me I was being courageous for going. Neither view really resonated with me because both seemed to assume a more hostile environment than I had encountered so far. "I guess the biggest risk is that I will learn something" was my reply to both. And soon I learned one more reason to be skeptical about overly gloomy pictures painted of the chances of relating to evidence-based guideline developers.

2. FINDING FRICTIONS WITHIN ASCRIBED FOUNDATIONS

Evidence-based medical practice purports to achieve these goals by enlisting numerous techniques for the management, evaluation, and application of clinical data into medical practice. Its hallmark is the hierarchy of evidence that consistently places the evidence derived

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from randomised controlled clinical trials on top (Sackett et al. 1996, 72). (Goldenberg 2006, 2622–2623)

So Maya Goldenberg writes in her contribution to a 2006 special issue in *Social Science & Medicine* titled "Gift Horse or Trojan Horse? Social Science Perspectives on Evidence-Based Health Care." This is also how sociological scholarship on EBM is commonly presented. As the chapter on EBM in the *Handbook of Medical Sociology* summarizes these sociological readings,

EBM represents a break with the past, when the most reliable evidence in medicine was pathophysiological, to augur a time where epidemiological evidence prevails (EBM Working Group 1992). Since the late 1980s, the goal of EBM has been to inform clinical decision making with an evaluation of a clearly defined hierarchy of available evidence. EBM elevated population-based, epidemiological studies with randomized controlled double-blind clinical trials to the apex of the "hierarchy of evidence" (Sackett et al. 1996). (Timmermans 2010, 309)

I was rereading these texts when working on a conference paper on guideline development and realized that much of the current trouble with EBM must have occurred in 1996. That is when epidemiology defined the hierarchy of evidence as its foundation, making study design more important than the match between knowledge produced and the issue at hand. At some point I got curious about precisely how the EBM founders, in their 1996 *British Medical Journal* paper "Evidence Based Medicine: What It Is and What It Isn't," phrased the privileged position of the RCT within the hierarchy of evidence. Following Goldenberg's page number in her citation (page 72), I could navigate straight to the heart of EBM epistemological politics. This is what I found:

Evidence based medicine is not restricted to randomised trials and meta-analyses. It involves tracking down the best external evidence with which to answer our clinical questions. (Sackett et al. 1996, 72)

Okay, not quite what I expected. But surely there will now follow a definition of what counts as "best" evidence, and that will, in the end, always be an RCT, with other forms of knowledge being of value only when "best" is not available, right?

To find out about the accuracy of a diagnostic test, we need to find proper cross sectional studies of patients clinically suspected of harbouring the relevant disorder, not a randomised trial. For a question about prognosis, we need proper follow up studies of patients assembled at a uniform, early point in the clinical course of their disease. And sometimes the evidence we need will come from the basic sciences such as genetics or immunology. (Sackett et al. 1996, 72)

That is a bit of a list as it is, since diagnostics, prognosis, and "sometimes" adds up to quite a range of questions for which study designs other than the RCT are "best." Perhaps there will be a rhetorical turn soon that indicates RCTs would ideally be available for such questions but too often aren't?

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It is when asking questions about therapy that we should try to avoid the non-experimental approaches, since these routinely lead to false positive conclusions about efficacy. Because the randomised trial, and especially the systematic review of several randomised trials, is so much more likely to inform us and so much less likely to mislead us, it has become the "gold standard" for judging whether a treatment does more good than harm. (Sackett et al. 1996, 72)

Avoiding false positives about efficacy of treatment is a lot more specific than arguing for a hierarchy per se. But then again, many questions *are* about treatment. And if they state the RCT is best for all treatment questions, that is still a big claim.

However, some questions about therapy do not require randomised trials (successful interventions for otherwise fatal conditions) or cannot wait for the trials to be conducted. And if no randomised trial has been carried out for our patient's predicament, we must follow the trail to the next best external evidence and work from there. (Sackett et al. 1996, 72 [really!])

Dave Sackett and colleagues, the very ones who were ascribed the politically non-innocent epistemic naïveté of placing the RCT on top of the hierarchy of evidence irrespective of the question at hand, seem to argue quite the opposite. Restricting the superiority of RCTs to the *effectiveness of treatment* questions and listing those questions for which other study designs are superior, they challenge the very foundations of EBM as ascribed to them. Although sociologists like Goldenberg could be seen as challenging what Gary Downey would call the "dominant image" of evidence that prevails in EBM, and helped call attention to what forms of knowledge it made in/visible (Downey 1998, 18), were they not also active producers *of* that image—only to then disagree with it?

Only partly. Following the history of EBM—for example, through current guideline development methods (which I do below)—shows how much the hierarchy of evidence *has* become infrastructured in an almost paradigmatic sense. But what if what happened after the 1996 paper is bracketed—even if strategically so? What if the paper is read more literally as pointing to the need for non-RCT knowledge and is mobilized to try to reopen a reflexive space for thinking about different knowledges for different questions? Could such a reading resonate with some of the frictions within (Kember 2003) EBM and help destabilize the idea that EBM has the hierarchy of evidence as its clear foundation? Isn't that a way to let the founders of EBM point to something quite close to the need for knowledges in the plural, rather than leaving that task up to the STS scholar? Could this result in inventive communication melting some of the passages between the shores? Steve Brown helps me take inspiration from Serres:

In order for there to be any kind of relationship between sender and receiver, some form of noise or interference, that is, an injection of difference, is required. This comes about by the very opening up of a passage, which inevitably exposes the signal to noise, and thus also to potential transformation. Serres then arrives at the interesting paradox that successful communication necessarily involves the risk of failure. Communication may be thwarted

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or 'betrayed' by the medium through which it passes. But if we take the position "downstream," at the point of destination rather than departure of the message, we may see this failure, this betrayal, as also the process of invention. (Brown 2002, 8)

Could my betrayal of sociological readings of EBM help inject a dose of difference in both EBM and sociology and lead to a passage, to invention? When challenging the foundations that sociology ascribes to EBM the shorelines do change. Fractal contours emerge. Straits of nuance appear that may become a way to navigate past the frozen passage that resulted from the—what Helen Verran (2001, 38) calls—"foundationist critique" by sociology of EBM; a critique of how both shores "assume a foundation to be out there that one can know about—either one world, the same for everyone everywhere and at all times . . . or multiple worlds in different places" (Jerak-Zuiderent 2015, 902). Could opening up such foundationist critique help produce travel as an adventure to be had? Or would the GIN conference make me end up in icier waters?

3. NAVIGATING THE FROZEN PASSAGES OF SOCIOLOGY-EPIDEMIOLOGY INTERACTIONS

"So, what is a sociologist doing at a guideline conference?" While I mistake the question for a conversation starter, the questioner turns away to greet another, more legitimate, conference participant.

This was right after an intriguing talk in a plenary session that focused on when RCTs, often considered the gold standard of clinical evidence, are *not* needed for developing guidance. The speaker had started out with a legendary example from a *British Medical Journal* Christmas issue on "Parachute Use to Prevent Death and Major Trauma Related to Gravitational Challenge: Systematic Review of Randomised Controlled Trials," a mock paper that argues that, because the authors were "unable to identify any randomised controlled trials of parachute intervention" and "advocates of evidence based medicine have criticised the adoption of interventions evaluated by using only observational data, . . . everyone might benefit if the most radical protagonists of evidence based medicine organised and participated in a double blind, randomised, placebo controlled, crossover trial of the parachute" (Smith and Pell 2003, 1459). The message: "Individuals who insist that all interventions need to be validated by a randomised controlled trial need to come down to earth with a bump" (1460). That is hardly the Christmas spirit, but it is for the *British Medical Journal*, which traditionally dedicates the Christmas issue to "light-hearted fare and satire."[8]

The speaker had taken the satire seriously—at the risk of killing a pretty good joke—and asked what made the parachute example "obvious." Listing similar examples, like sewing arms back on after "alligator rip off" (the speaker was from Australia) and the "mother's kiss technique" for taking out a bee that is stuck in a child's nose (keeping the other nostril closed and blowing into the child's mouth), he argued

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that they shared important similarities. The effect of the intervention is "mechanically obvious," there is a "rapid effect with large magnitude," and the "relative risk" (an epidemiological term for the probability of an event occurring irrespective of whether one is exposed to the intervention or not) is calculated as being "beyond the realm of bias." In such cases, the speaker argued, there is no need for evidence from RCTs.[9]

I found it interesting how the talk highlighted that quality of evidence is contextual and not solely dependent on study design, but because the question was raised only about when *RCTs* are not needed, I wondered if, again listening to this speaker literally, he thought it could be extended to other designs too. When would *other* types of knowledge *not* be necessary for developing guidance? For example, when would an ethnographic study of patient experiences with an intervention not be needed? During the break, I waited till others had asked their questions and then approached the speaker. Before replying to my question, he asked, "What is your background?"

"I am a social scientist interested in questions of knowledge standardization," I replied, adopting a label I sometimes use when I think "STS" will require so much explanation that it may not travel well. I wanted to focus on the content of the conversation, not lose my interlocutor in a wordy description of a field. But instead of an easier disciplinary presentation surely helping the conversation, as I thought, that's exactly as far as the conversation went.

Should this even have come as a surprise? Shouldn't I have known that social scientists don't have the best reputation within the EBM community? For example, the "Parachute" paper mocks the social sciences under the subheading "The Medicalisation of Free Fall": "It is often said that doctors are interfering monsters obsessed with disease and power, who will not be satisfied until they control every aspect of our lives (*Journal of Social Science*, pick a volume)" (Smith and Pell 2003, 1460). Whereas I imagine a generic *Journal of Social Science* to be full of frictions within, that is not what epidemiological interlocutors imagine it to be. I had surely managed to make myself more legible to the speaker but in exactly the wrong terms; I had become part of a side that was party to so many previous tensions between proponents and critics of the RCT. Tensions between medical researchers claiming privileged epistemic access to a foundation of biological facts and sociologists claiming privileged epistemic access to a foundation of social complexity. Becoming legible in those terms made my question appear a poorly disguised attack the speaker would not spend another moment on. Enough other, legitimate conference participants for him to not want to waste time repeating the Science Wars.

Standing there, staring at the back of the speaker, I became an embodied reminder that being "third-instructed" not only means living without the comforts of disciplinary specialism but also requires avoiding the problematic historical encounters between disciplines. The pitfalls of the journey, the thick ice encountered, the dangers of frozen passages, all were shaped by how similar travels played out in the past. In fields like epidemiology, previous travels by social scientists seem to have left thick

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layers of ice that obstruct what could be crucial straits in navigation. I will never know if this speaker would have entered the conversation if I had given a wordy description of my interests, but at least I was right about running the risk of learning something—namely, that disciplinary presentation matters and that disciplinary clarity can work to one's disadvantage. That could have been somewhat of a liberating lesson for an STS scholar if not for my concern about how conversations at this conference would unfold. Let's see what happens after the break.

4. TIME-PRESSURE, KNOWLEDGE-PRESSURE: THE WISDOM OF PUBLIC HEALTH

What should a government do when there are, say, reports of malaria infections in Greece that appear endemic? Should there be export restrictions—for example, on car tires, because water tends to accumulate in them, possibly allowing larvae to survive transport and spread the disease? Should there be other restrictions? For which products or persons? And how can a government know what actions to take?

After the coffee break, this question is asked in a workshop called "Development of Public Health Guidance in Settings with Lack of Evidence and Lack of Time." One of the session organizers, who gives the introduction, makes clear that the answer is not "Give us ten years and lots of funding, and we'll do a range of RCTs to test different interventions, after which we'll do metareviews of those, and then we'll have high-quality evidence for you, dear government officials."[10] Endemic malaria in Greece is presented as an example to point to the strong mismatch between the knowledge needs for developing guidance for complex public health questions and current guideline development methods, particularly the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology.

GRADE firmly abandons the ideas that I had been so happy to find in that 1996 EBM paper about the importance of matching the preferred type of study to the clinical question at hand. GRADE works with tables that classify reported findings on the basis of study design: RCTs start out as high quality, whereas observational studies or any other designs start out as low or very low quality (Guyatt et al. 2011, 386).[11] GRADE is generally seen as an important development in making evidence assessment more transparent and is close to becoming an obligatory passage point if not a paradigmatic feature of current guideline development. Lead developers of this approach are based at McMaster University, where Dave Sackett established Canada's first Department of Clinical Epidemiology & Biostatistics. Yet in GRADE the dreaded hierarchy of evidence that defines what counts as high-quality evidence on the basis of study design from the outset is foundational to the approach. Hamilton, Ontario, by now clearly goes far south of the Northwest Passage. The frozen passage that emerges clearly isn't just a problem for STS scholars; it is even more so for those in public health who have to respond to the types of questions the public health guideline developers at this session are asked.

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In a clever strategic move, the *British Medical Journal* paper that helped establish the dominance of the approach is titled "GRADE: An Emerging *Consensus* on Rating Quality of Evidence and Strength of Recommendations" (Guyatt et al. 2008; emphasis added). This title draws on the history of guideline development, in which systematic consensus statements played a major part, while giving the meaning of "consensus" quite a twist. Consensus statements became institutionalized with the launch of the Consensus Development Program by the US Department of Health in 1977, which "served as a model for consensus conference programs developed in many other countries" throughout the 1980s (US Department of Health and Human Services, n.d.). This approach had the same aim as current guideline initiatives, that is, to produce "unbiased, evidence-based assessments of controversial medical issues important to researchers, healthcare providers, policymakers, patients, and the general public" (US Department of Health and Human Services, n.d.), but knowledge appraisal was primarily considered a professional rather than a statistical exercise for which the program drew on the RAND Delphi method for consensus conferences. Delphi uses statistics, but mainly in the supportive role of presenting expert judgment. This approach is largely abandoned in current guideline development, and the Consensus Development Program was "formally retired" in 2013 (US Department of Health and Human Services, n.d.).

Methods that have replaced it, like GRADE, use the hierarchy of evidence to classify the knowledge that experts bring to the table as low or very-low quality from the outset. Compared with how consensus statements considered expert knowledge, such methods somewhat resemble a landslide. So for GRADE to draw on the language of *consensus* for its legitimacy, not merely through the title of this paper but also by listing the large number of organizations that adopted it on its website, is a little more than ironic. Rather than considering GRADE a new *consensus*, those concerned that current methods have a narrow understanding of what counts as knowledge think the focus on having a majority vote gives them, as I would later learn, "a rather evangelical feel" about how the approach is being positioned (GIN board member, personal communication, September 3, 2012). The public health guideline developers at this well-attended workshop, for example, clearly do not feel included in this emerging consensus.

But neither do they have a clearly articulated alterative guideline development method to challenge this dominance. When the lead organizer of this session from the European Centre for Disease Prevention and Control asks who of the fifty-something people in the audience recently had good experiences with developing or using other methods for including different knowledge in public health guidance, one person raised a hand. *One* in a room full of guideline developers for public health—who have to integrate wide-ranging knowledges while under constant time pressure. The lead presenter seemed puzzled by this but went on to stress that time pressure is merely an entry point into a broader discussion on how to develop guidance given the inherent uncertainty in evidence. In the case of developing guidance

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on endemic malaria, time pressure is an important reason for challenging the solution of RCTs as providing more certain knowledge. But more profoundly, he stressed, uncertainty is inherent in RCT evidence too, which means guideline developers have to stop "measuring with one stick." A more variable set of evidence-appraisal practices could be considered a dire need for the transdisciplinary collaboration that guideline developers gathered here have to engage in.

To again take inspiration from Serres, in the reading of Brown, the concern of the guideline developers in this conference session seems to require guideline practices that are based on "understanding communication between forms of knowledge":

> Such communication is noisy, it is a mixture of messages subject to transformation. What Serres then describes are the connections, the translations that occur as part of the distribution of knowledges. Serres then advances a particular view of wisdom as that which is garnered by occupying the middle position, right in the midst of the confluences and mediations. (Brown 2002, 12)

If wisdom is what these public health guideline developers have cultivated rather than methodological rigor, would that make for a better chance of connecting their puzzles to STS concerns about standardizing situated knowledges?

5. INFRASTRUCTURING DIFFERENT KNOWLEDGE

The talk the main session convener and I have this time during the break doesn't end with a rhetorical question but with a plan. He has a medical background but also studied sociology during his freshman year, which surely troubles the understanding of the human sciences and EBM as shores connected by a frozen passage. It is not quite clear which coast he belongs to. Too many fractals for that. Too many frictions within.

Our conversation revolves around the dominance of the hierarchy of evidence that public health guideline developers were struggling with in the session. He states that this is especially problematic for public health, whereas I indicate that I came to this session without a particular interest in public health: I saw the main value of the session in pointing to a general problem in *all* of guideline development, with public health as a setting where confronting that problem head on is unavoidable. I refer to the 1996 *British Medical Journal* paper and suggest that the current state of guideline development is largely inconsistent with its founding principles. I also refer to the study I will be presenting at the conference and the related larger project that showed a direct relationship between the amount of RCT evidence on an issue and how well that issue was addressed in Dutch guidelines (Zuiderent-Jerak et al. 2011). This triggers his interest, and he immediately thinks about other guideline developers—for example, in the field of oncology care—who have expressed similar concerns about where guideline development is heading. When I suggest that he seems to argue that in public health, and in other areas, current guideline development methods lead to

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the crowding out of other knowledges that are crucial for meaningful guidance, he recognizes that this is a different language for addressing a shared concern (that all knowledge gets "measured with one stick"). By a stroke of luck, he turns out to be a GIN board member and we agree that the question on how to weigh and include different knowledges should probably be a core issue for many guideline developers and that GIN as an association can play an important role here. The emerging plan is threefold: (1) conduct a survey and follow-up interviews of GIN members about the methods and approaches they use for knowledge appraisal and integration, (2) organize a workshop on this topic at the next GIN conference, and (3) write a position paper to kick off the discussion.[12]

The closing plenary of the conference strikingly points to the relevance of this plan, as well as to the opposition it may face. A Yale professor and coauthor of the new Standards for Guideline Development presents the approach developed under the aegis of the US Institute of Medicine and published as *Clinical Practice Guidelines We Can Trust* (Committee on Standards for Developing Trustworthy Clinical Practice Guidelines, Institute of Medicine 2011). This document mobilizes a highly restrictive definition of "guideline," and the speaker argues that, for guidance documents to even carry the label of guideline, recommendations need to be based solely on high-quality evidence, by which he means that it should come from RCTs. He provides compelling examples, but they are all regarding the effectiveness of clinical therapies, which few in the audience would disagree with. But the restrictive policy would pose huge problems for the knowledge needs for other types of questions. Unsurprisingly, the discussion becomes a rather fierce controversy. If guidelines can be developed only for issues that have fully conclusive RCT evidence, a member of the audience concludes, we have a "perfect example on when we do not need clinical guidelines!"—a comment that gets a round of applause. The questioner goes on to explain that the Institute of Medicine definition makes the difference between evidence summaries and clinical practice guidelines negligible, which reduces the latter to implementation tools for what is already known rather than guidance documents for complex clinical questions. A second questioner, a former GIN president who has published on the need for moving beyond the evidence in EBM (see Burgers and van Everdingen 2004), brings home that point, saying, "The scope of this definition is much narrower: it excludes all documents that are not evidence based but still do guide doctors and patients in doing their work." But the way the question is phrased ("not evidence based"), which equates evidence with RCTs, makes the rhetorical reply easy: "The question is: '*should* such documents assist doctors and patients in taking decisions?' We have many such documents and they really should diminish. There is a place for carefully constructed documents that are partly evidence based and partly carefully consensus based. However, we do not call them guidelines."

At the end of the closing plenary, the chair of the GIN board presents the history and future of the network and describes how, from systematic consensus statements

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in the 1970s, via large national guideline programs in the 1980s (e.g., US Agency for Healthcare Research and Quality) and 1990s (many other countries), twenty-first-century guideline development now mainly consists of international collaboration. He describes how GIN at that moment has six working groups and proposes that the future of GIN should be geared toward harmonization of guideline development. But he also states that this can be achieved by two main routes: as networked collaboration or as a center of authority. He makes it clear that he is not willing to take the latter route,[13] which seems an elegant way to further trouble the debated, authoritarian approach proposed by the Institute of Medicine.[14]

Importantly, if the harmonization he envisioned required a *network* approach—and this professional organization uses working groups as its infrastructural format—the public health session chair and I realize that we need to add an item to our emerging plan, making it fourfold: (4) establish a working group on appraising and including different knowledge. Traveling the Northwest Passage just became the adventure of setting up a new working group within GIN. Not much of a hostile crowd after all.

6. KEEPING OPEN ICY PASSAGES IN IMRAD STRUCTURE

EXECUTIVE SUMMARY[15]

Introduction: Despite the nuanced ideas within EBM about the importance of appraising and including different types of knowledge for different guideline questions, the methodology for developing clinical practice guidelines has generally focused on assessing (systematic reviews of) RCTs. There is a real need for methods that focus on appraising and including other kinds of knowledge in a robust way. The questions in this study therefore are: what methods are available for appraising and including these different types of knowledge? And what experience do guideline developers have with these methods?

Methods: An internet survey was carried out among all G-I-N members and those attending the G-I-N annual conference in 2012. All 130 responses were analyzed and used for selecting respondents for follow-up interviews. Interviews were held with guideline developers from Australia, Canada, Colombia, Germany, the Netherlands, Norway, Spain, the United Kingdom, and the United States. Results were presented at the G-I-N '12 conference, and further development steps were taken during a well-attended post-conference workshop following that same G-I-N meeting.

Results: Despite the good response rate of the survey (32.5%) and the high number of active participants in the post-conference workshop (around 55 guideline developers), there is limited experience of methods for appraising and including different kinds of knowledge. Only just over 50% of the respondents involved in guideline development within the last three years reported having any experience with using appraisal methods for including non-RCT knowledge. 85% of the methods are used to address clinical questions, rather than e.g. patient experiences (5%), quality of care considerations (4%), user/professional considerations (3%), organizational considerations (3%), cost considerations (1%), or safety, ethical, or legal considerations (all 0%). The reasons for including other types of knowledge was reported to be the lack of (systematic reviews of) RCTs for such questions, or a high

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availability of RCT evidence that addresses the wrong issues or that is irrelevant to the setting. Developers who reported using methods to appraise and include different knowledge, scored usefulness a 5.6 on a 7-point Likert scale. They positively evaluate such methods, despite difficulties they report with appraising and including different knowledge within the framework of evidence-based guideline development.

Analysis: While the project aimed at identifying a wide range of methods for the appraisal and inclusion of a broad array of types of knowledge, methods are mainly used for addressing clinical questions about treatment interventions. When RCTs and systematic reviews are lacking, guideline developers mainly focus on appraising and including observational studies for clinical questions. Some promising initiatives for evaluating other types of knowledge have been identified, such as methods for assessing the quality of quality improvement (QI) knowledge, for performing secondary analysis of qualitative narrative interviews on patient experience, and for assessing economic and ethics questions through checklists.

Discussion: Given the limitations of the availability and suitability of RCTs, the importance of methods for appraising and including different knowledge is well recognized by guideline developers. This should come as no surprise, given the nuanced ideas among the founders of EBM about the dangers of equating EBM with RCTs. Up to now most resources and attention have been used on methods for appraising and including (systematic reviews of) RCTs. The guideline community has still a way to go to develop robust methods for appraising and including non-RCT knowledge. This leaves guideline developers with many problems of substantiating recommendations based on the best external knowledge available. This either leads to ad-hoc ways of appraising and including such knowledge, or to its exclusion from guidelines that thereby are at risk of becoming RCT-biased.

Recommendations: The issues identified in the project deserve the attention from the guideline development community. There is certainly enthusiasm for further collaboration among guideline developers. Given the role of the Guidelines International Network in facilitating such collaboration, a G-I-N Working Group on Appraising and Including Different Knowledge (AID Knowledge) seems an important and appropriate next step.

Not without discussion, this working group was approved by the GIN board in 2013. In the next section I discuss one way the group transformed the focus on infrastructural (methods) development that I thought was the crucial STS content of this initiative. I should have been warned, though, that what I thought was STS content was likely to get transformed by the journey as well.

7. A LESSON FROM STAYING BETWEEN THE SHORES: IT'S THE EPISTEMOLOGY, STUPID!

I've been going on about this for some time now, a line of thought that runs as follows: The mistake of much of the sociological criticism of EBM was that it portrayed guideline developers as stuck in poor epistemology, one that privileges RCT evidence over other knowledges through the hierarchy of evidence. But if we read the founders of EBM differently, more closely, and while attending to the diverse understandings of what counts as good knowledge among guideline developers, such as those in public health, it becomes clear that their epistemology is far from naïve. Some of the most sophisticated critiques of RCT evidence come from *within* this community.

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So the sociological critique of EBM *epistemology* has obfuscated a much more consequential development of the EBM *knowledge infrastructures* for appraising a highly limited set of study types in tremendous detail. The dominance of GRADE, more than a dominance of a limited epistemology, is a dominance of limited knowledge infrastructures. This relocates the need for action into the heart of developing novel knowledge infrastructures—like appraisal methods—for a wider range of knowledges.

I've made this argument in different settings, including during presentations at the annual Society for Social Studies of Science (4S) meeting and during a workshop at the annual GIN conference. The focus of the AID Knowledge Working Group on highlighting such ongoing methodological developments is, I judge, a way to turn STS knowledge on knowledge infrastructures, as a site for doing politics, into an STS sensibility within the guideline development community. We may be, for lack of a better word, making progress. And that's when I get called back.

We're in an AID Knowledge Working Group meeting at the 2015 Amsterdam GIN conference. I've outlined the agenda, which includes efforts to harvest some of the methodological developments going on among guideline developing agencies. In line with the vision of networked collaboration, we want AID Knowledge to foster a community of practice that connects different initiatives regarding methods development. I've invited four members of AID Knowledge to give five-minute presentations on cutting-edge developments in promising sites, such as on public health and social care at NICE, the UK National Institute for Health and Care Excellence that has kept the same acronym over the years but was founded in 1999 as the National Institute for Clinical Excellence. Adding such an increase in scope (from clinical to health and social care) also comes with new methods needs, the kind AID Knowledge would like to learn from—especially because NICE leaders have been involved in developing AID Knowledge right from the start.

Another talk focuses on occupational health, in which uncertainty in evidence is often approached not through increasing the number of studies but through applying the precautionary principle. Two other talks focus on recent developments in public health based on a project some AID Knowledge members, including me, were involved in (Harder et al. 2015) and on current developments relating to guidance for rare diseases. My hope is that during the next agenda item, "Plan of further action of AID Knowledge," we can collectively find ways to highlight such developments, perhaps by building a database of good practices regarding guideline methods for different questions. But the discussion takes quite a different turn.

The group starts to discuss how all methods try to justify themselves in relation to what one of the members, drawing on Ian Hacking's *An Introduction to Probability and Inductive Logic* and *The Taming of Chance* (Hacking 1990, 2001), calls "frequentist reasoning." At least I was right about guideline developers and researchers not being epistemologically naïve! His concern is that, without attending to what he calls different styles of reasoning, guideline development methods for different

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knowledge will be set up for an impossible task: justifying such knowledge within a frequentist epistemological frame. All efforts to highlight methods for appraising different knowledges will, he fears, either be ignored or will be slotted into a hierarchy of evidence that still starts with RCT-derived evidence and adds other appraisal methods later—but in RCT terms. The hierarchy of evidence is easy to uphold, he argues, according to the frequentist epistemological assumption that the more we observe a (controlled) phenomenon, the better our knowledge of it. RCTs are inherently better at this, in spite of drawbacks that come from prioritizing internal validity (the methodological rigor of the study design) over external validity (the extent to which the frequently found result can be extrapolated to the single-case scenario in the world). Without pointing to the limits of frequentist reasoning, and without highlighting alternatives, appraisal infrastructures for all other knowledges will, he argues, continue to look inherently less reliable and knowledge inclusion will be on unequal terms because other knowledges will have the wrong frequentist measures applied to them.

Many group members respond enthusiastically, and I start to realize quite soon that, although I am probably not the only one struggling with some of the epistemological notions discussed, I *am* probably one of the last people left in the room who is ambivalent about writing a more philosophically oriented paper on styles of reasoning in relation to appraising and including different knowledge in guidelines. I guess this is part of the adventure to be had: a philosophical excursion that makes me read up on philosophy of science. The working group members seem convinced that my proposal of entering the open passage of knowledge infrastructures rather than the icy one of epistemology would be a dead end, because we would still be stranded at the shore of current EBM and its frequentist reasoning. What they propose instead is to use styles of reasoning as an icebreaker to open up a strait that would get us to knowledge infrastructures, no doubt, but not without having first challenged the politics of knowledge hierarchies. Shifting from ontological to epistemological politics; not something I often see at STS conferences or in STS journals these days, but something that AID Knowledge—and a leading EBM journal—turned out to be interested in (Wieringa et al. 2018).[16]

I must admit it felt quite odd to be reminded of the importance of epistemology by the guideline developers in AID Knowledge. Being trained in a version of STS that considers the action to be located in ontology rather than epistemology, the latter leaving you blind only to the "missing masses" in your analysis (Latour 1992), I had turned that disciplinary suggestion into a disciplinary stereotype that made me feel infrastructures were an inherently more interesting site for analysis and intervention than styles of reasoning. I could have been reminded of the entwined nature of ontology and epistemology through feminist STS scholarship but had to be called back by members of the AID Knowledge Working Group, providing a fine example of the importance of attending to STS sensibilities out there (i.e., how such sensibilities

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"are by no means the exclusive domain of STS scholars"; Downey and Zuiderent-Jerak 2017, 228). These guideline developers weren't going to fall for my disciplinary overestimation of the material agency of knowledge infrastructures without attending to the epistemologies that they believe will easily swallow them. They wouldn't want to have their commitment to different knowledges end up in the dead end of making knowledge infrastructures live up to frequentist demands. What did I learn from this shift of focus for AID Knowledge about staying between the shores of EBM and the human sciences?

8. CONCLUSION: COMMITMENT TO THE THIRD SPACE AS NEITHER THE SAME NOR DIFFERENT

Moments like the one I encountered here may be helpful for thinking through what it could mean to follow Serres's suggestion that we "seek to occupy the spaces of transformation which lie between—neither one nor the other but the 'third space.'"

In two readings of the third space, something important would be lost. First, if we read "neither" as equaling "not," the third space would risk becoming a shoreless ocean rather than a passage that is shaped by its shores. Although to occupy the third space it is crucial not to get stuck on either shore, it is equally important to cultivate a pertinent awareness of how the shores relate and to be surprised by them. They indeed are "jagged . . . , sprinkled with ice, and variable"; they are "more fractal than truly simple" too. Plus, quite a few are trying to change the shorelines, possibly opening up passages that seemed impassable at first. Surveying the shores and the thickness of the ice in the passage can manifest in the form of a research funder proposing a shared conference talk, a philosophically trained guideline developer referencing Ian Hacking, or an STS scholar closely rereading a founding EBM paper. In all of these, the awareness of the shores helped in testing the ice, finding an opening. The one time I chose disciplinary legibility over sensitivity to the shores, the passage froze up in less than a moment. If the third space is explored in the oscillation between the shores, the nomadic nature and elasticity of STS may become its crucial strength. Inhabiting an overwhelming range of academic departments, disciplinary positionings, and publication venues, which is sometimes regarded as one of the main risks STS as a discipline faces, could well be a main source of vitality that comes from trying to navigate between the shores while being involved in changing them.

In the second limited reading of the third space, "neither" would be thought of as "hybrid." It is true that the lead organizer of the public health session had studied sociology as a freshman, and that the lead author of the paper on styles of reasoning was working on a philosophically inspired dissertation on EBM, but that surely does not apply to all AID Knowledge Working Group members, while I would consider all of them as *tiers-instruit*. Where a hybrid is something made of two materials, two strands of thought, two somethings; AID Knowledge thrives on the commitment to

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perpetual translation that comes from being "neither"—at least not in any singular form. This commitment is made out of necessity by public health guideline developers, for whom the "comforts of disciplinary specialism" that dominate epidemiology would render their guidance useless. A commitment to perpetual translation can also be infrastructured, as in the case of the Dutch College of General Practitioners, who have as one of their operating principles that professionals involved in guideline development also need to be practicing GPs. Furthermore, AID Knowledge is intended to be a third space in itself: a semiorganizational, quasi-epistemic space that helps exchange the comforts of disciplinary specialism for the risk of perpetual translation. It is not a hybrid of the human sciences and epidemiology. It is neither, but it does take a keen interest in both shores and how they may limit or enable appraising and including different knowledge in guideline development. Importantly, the space is also occupied *together*, which is why spaces like AID Knowledge can become crucial for strengthening each other's sense of being third instructed.

To pursue a commitment to the third space, perhaps a conundrum like "neither the same nor different" would then be more generative. Sounds esoteric. Indeed, I am most familiar with this phrase used by spiritual guides explaining the continued flow of mind and matter to a new existence, trying to avoid referring to an essential "I" that transmigrates between matter, as invoked by the term "reincarnation." That may be an unexpected way to end a chapter on third spaces between the human sciences and EBM, but didn't Serres and Brown warn us to seek our instruction neither from science alone nor the sacred?

ACKNOWLEDGMENTS

I want to thank all the members, past and present, of the AID Knowledge Working Group for their collaborative spirit and continued commitment to knowledge inclusion that is equally rigorous as it is situated. The GIN Board of Trustees, as well as the GIN Office, have continued to provide invaluable support to the activities of AID Knowledge. Special thanks are due to Frode Forland, Fergus Macbeth, Beth Shaw, Sietse Wieringa, Sue Lukersmith, Dunja Dreesens, Philip van der Wees, Duncan Service, Sonja Kersten, Elaine Harrow, Anne Docherty, and Jenna Docherty. Hsin-Hsing Chen and Gary Downey made important and generous comments to the demo account, as did one of the anonymous reviewers. A previous version was discussed during the international workshop "Formalised Procedures and Informality in Research Practices," at the Theory of Science department of the University of Gothenburg, where it benefited much from comments by Loes Knaapen, Stefan Timmermans, Ingemar Bohlin, Morten Sager, and others. Start-up funding for AID Knowledge and its collective publications was provided by the Guidelines International Network, the Dutch Council for Quality of Healthcare, and the Dutch Association of Medical Specialists.

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NOTES

1. Cited in Brown (2002).

2. For an exploration of this passage in relation to medical informatics and integrated care, see Bal and Mastboom (2007).

3. The annual conference of the Guidelines International Network (GIN), the professional association of guideline developers for health-related topics.

4. Zuiderent-Jerak, Jerak-Zuiderent, and Bal (2010).

5. Zuiderent-Jerak et al. (2011).

6. For an early rendering of it, see Zuiderent-Jerak, Bal, and Berg (2012).

7. Details regarding the history of evidence-based medicine are documented elsewhere and are beyond the scope of this demo account.

8. See https://www.bmj.com/about-bmj/resources-authors/article-types/christmas-issue.

9. For related arguments from within the EBM community about when RCTs are not necessary or preferred, see Aronson and Hauben (2006), Glasziou et al. (2007), and Golder, Loke, and Bland (2011).

10. For a study on how US public health and regulatory agencies entwine judgment and systematization to make sure such action in relation to food outbreaks is fast but right, see Boyce (2014).

11. Several versions of this classification exist, some of them including "any other evidence" as the very-low category, with observational studies classified as low. Also the nomenclature has shifted from quality of evidence to confidence in evidence, which, while clarifying that a high classification is a statistical notion rather than a qualitative judgment, further narrows the focus on what counts, because the whole classification becomes statistically frequentist, without making that assumption explicit. These more nuanced developments of GRADE leave untouched the basic epistemic assumptions and—while interesting—are beyond the scope of this demo account.

12. Published as Zuiderent-Jerak, Forland, and Macbeth (2012).

13. This position resonates strongly with the detailed analysis of the development and institutionalization of guideline development in GIN performed by Loes Knaapen (2013), and because Knaapen has interviewed many in the GIN community, including this chair of the GIN board, there is every chance this position was further clarified for all involved during those conversations.

14. This is an approach that needs to be understood in the context of the US marketized health care setting, in which care providers at times use guidelines as part of their marketing strategy and many guidelines are not developed by independent guideline development agencies. This contrasts with guideline development practices in many welfare states, which explains part of the difference in approaches proposed to regulate guideline development.

15. IMRAD stands for the "introduction, methods, results, and /analysis discussion," which is a standard structure for articles in the biomedical sciences. See, for example, Day (1989). Paragraphs taken from Zuiderent-Jerak, Forland, and Macbeth (2013), 3–4.

16. This is not to say the writing or publishing of the paper was necessarily smooth, and it did involve a rejection by a leading US-based medical journal on the basis of reviews that were nothing less than silly. Not all EBM is equally epistemologically nuanced.

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10

CRITICAL PARTICIPATION

Inflecting Dominant Knowledge Practices through STS

Gary Lee Downey

"How do we change the culture?" Two senior administrators from US engineering schools recently approached me for help answering this question. They share a widespread dissatisfaction with engineering education that views it as producing engineers with technical knowledge and skills only. Their critique places blame on passive learning, and they aim to scale up practices of active learning to enable students to gain additional knowledge and skills.

Yet they face continuing resistance from engineering faculty and had come to the conclusion that engineering has a cultural problem. Together with other activist educators, they had agreed at a workshop that the core issue at stake in engineering education is "not about curricular change but rather how to bring about cultural change."[1]

I heard this request through an STS filter.[2] I heard it as an invitation to help them confront and possibly reframe a pervasive distinction in engineering that demarcates practices of technical knowledge from practices of social knowledge. Such demarcations are a familiar finding in STS critiques of technoscience. Versions in engineering tend to privilege practices of mathematical problem-solving in the engineering sciences.[3] They devalue and subordinate practices of social knowledge that may nonetheless figure significantly in the identities and commitments of engineers and the trajectories of engineering work. In this case, it is knowledge about culture. These activist educators wanted to know if what they saw as stubborn faculty commitments to "transmissionist" practices of teaching and learning was somehow about culture. If so, how could they go about changing it?[4]

Demarcations of technical knowledge from social knowledge in practices of technoscience provide fertile sites for sociotechnical critiques and knowledge production in STS research. They also challenge STS scholars and practitioners to achieve travel for STS findings and knowledge claims into the ecologies in which demarcations

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reign. Achieving travel for STS knowledge involves expressing it through techniques, devices, infrastructures, selves, and other STS sensibilities and then attaching them in empirical settings beyond the boundaries of the field.[5] This invitation confronted me with a particularly vexed issue faced by projects in STS making & doing: how to express and attach STS knowledge in ways that actually inflect and reframe dominant knowledge practices?

Alongside the activist educators, my own critical analyses of the making of engineers have found engineering to confront itself with a significant cultural problem, one that can make engineering practices self-limiting. Yet we have understood the issue differently. The educators diagnosed a cultural problem that surrounds the technical core of engineering practices and, hence, lies beyond the engineering science curriculum. My sociotechnical accounts have rooted a problem precisely within the technical core of engineering practices. From this point of view, any self-limitation in engineering practices starts in the heart of engineering science calculation rather than in practices around it.[6]

The advocates of active learning were seeking an expert consultant to help them overcome resistance from stubborn engineering faculty. I was seeking practices to enable sociotechnical knowledge to travel into and inflect their world, persuading them to relocate the cultural problem within the technical core and, hence, the curriculum. When reframed in sociotechnical terms, I claimed, the resistance they felt to practices of active learning certainly included but also extended beyond specific techniques for teaching and learning. It is born in the settled knowledge, identities, and commitments of those faculty as engineers.

The moment appeared to provide an opportunity for STS knowledge travel. Might I be able to express my sociotechnical knowledge through practices that engage and attach to their stated interest in culture change? I thought perhaps that our overlapping critiques of technical learning might facilitate this attachment. Also, what could I learn from the experience as an STS scholar committed to producing and expressing STS knowledge for travel (Downey and Zuiderent-Jerak 2017)? At the outset, I hoped for such reflexive learning to be about developing practices of knowledge expression and attachment that could possibly inform other STS projects to inflect dominant knowledge forms in science, technology, and medicine. Akin to these activist educators, technoscientists in many fields are now showing interest in the social undersides of their knowledge hierarchies. However, the most important learning through this project came as a surprise—a provocation to reframe its heart as well.

RECOGNIZING TRAVEL WITHIN STS SCHOLARSHIP

In a ninety-minute teleconference, I shared practices from a course I had developed to help engineering students learn to identify and reflect critically on their knowledge, identities, and commitments.[7] Engineering Cultures offers a view of culture within

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engineering that explores how emergent infrastructures of engineering formation and work produce and enact dominant images of engineering knowledge and engineers, images that vary dramatically across time and from place to place (Downey 2008; Downey et al. 2006). It calls attention to practices that would-be engineers must perform in order to move successfully through those infrastructures. It shows how those practices challenge engineers to accept and then embody localized configurations of knowledge, identities, and commitments. Students in the course do not have to accept that engineering knowledge is inherently normative to recognize and appreciate that the practices involved in becoming an engineer and doing engineering work certainly are. Learning to trace over time and compare infrastructures of engineering formation in, say, Korea, Japan, France, Germany, the United Kingdom, and the United States makes the point both clear and, hopefully, interesting. Then by role-playing others, students practice critically positioning themselves.

The educators in the teleconference began picturing infrastructures that have challenged them during their careers and shared examples from their experiences moving through them. Turning to the issue of culture, I suggested that they try to engage colleagues who resist by first trying to understand and document the resistance. Dominant images of engineers and engineering have certainly changed and will change again, but that doesn't make it easy to produce change, and persistence matters. To build their own initiative, might they consider recruiting faculty and students at their institutions to join them in identifying the knowledge, identities, and commitments they gained or did not gain by learning engineering through existing techniques? They could then ask for help examining how practices of active learning might challenge or reframe these outcomes. At stake in their project, I suggested, are core issues of knowledge, identity, and commitment: What counts as engineering knowledge? What does it mean to be an engineer? What do engineers seek to accomplish through engineering, and for whom? Assessing opportunities to attach active learning to engineering pedagogy then involves tracking interactions between its practices and existing practices in as much detail as possible.

The educators expressed enthusiasm. One later wrote in an email that he found it helpful, in particular, to see curricula and knowledge as part of culture in engineering rather than apart from it. And five months later, a draft 750-word position statement about their project arrived. A publication for US engineering educators had invited it. Its argument culminated in a final call that made reference to me as an authority and drew content from the teleconference. They meant it as a compliment and asked for my approval to publish.

However, it didn't say what I had said—at least as I see it. I had offered practices with STS sensibilities, while the statement reinscribed a demarcation between technical and social knowledge. The statement did so by, once again, externalizing culture from engineering practices, this time with greater specificity. It presented the technical "content" of engineering as located "within an established culture,"

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drawing on a common popular image of culture as a kind of container. I offered edits to pull cultural meaning back into the engineering science curriculum, which they accepted and published (Buffinton and Manno 2017). But the exchange left me wondering if they got my sociotechnical claim or not. By asking them to add practices of critical self-reflection, whom was I actually asking them to become? Had the exchange positioned me to critically engage their initiative further?

In this demo account, I open up this small project to discuss what is at stake when expressions of STS knowledge confront a dominant knowledge form in technoscience. Focusing scholarly attention on the travel of STS knowledge beyond the boundaries of the field has the effect of flipping the framing and priorities of STS scholarship. It prompts us to examine, justify, perform, and even define STS scholarship by looking at it from the outside in as well as from the inside out.

When examined from standpoints outside the field, practices that express STS knowledge emerge as diverse nomination of things they call sociotechnical. These nominations seek to enter and critically engage ecologies filled with practices, people, and things that take for granted and perform persistent knowledge forms. The salient knowledge question becomes, How can we better understand interactions between sociotechnical nominations and persistent knowledge forms in order to genuinely achieve flows of STS learning into those arenas and back again into subsequent iterations of analysis, nominations, expressions, and attachments?

When we begin by examining and assessing sociotechnical knowledge from inside the field outward, the usual standpoint in scholarship, we can be distracted by internal competitions for visibility, influence, and virtuosity that can sidetrack us into zero-sum games of academic credit and status. STS critique nominates versions of the sociotechnical, positioning them strategically in relation to other versions. Critique alone has an immediacy to it. The critical account often concludes with hopeful sentences that imagine how the empirical arena might look once its creations have diffused widely and are in use. Nothing further is necessary to warrant publication. Attending to the actual practices and problematics of travel can get postponed or omitted entirely (cf. Fried 2019).

When we include within STS scholarship following how sociotechnical practices critically engage persistent knowledge forms, we thereby experiment with shifting our subject positions to external locations. We begin analyzing those practices as *external projects* within our work. Assessing critical scholarship from external standpoints motivates foregrounding the issue of *knowledge travel* at the outset rather than as downstream supplement. A central concern becomes assessing the practices through which sociotechnical knowledge actually does or does not travel beyond the boundaries of our field, critically engaging knowledge forms where they thrive and facilitating sociotechnical learning.

I organized the teleconference as an experiment in *critical participation*, by which I mean developing, expressing, and attaching sociotechnical practices to engage and

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inflect a dominant knowledge form in science and technology without necessarily dismantling or wholly replacing it (Downey 2009; cf. Smith 2021; York 2018). Participating critically in practices that enact and sustain a dominant knowledge form involves at least three sets of practices that coexist and interact without clear or necessary sequence. Together, they focus attention on flows of sociotechnical learning and reflexive sociotechnical learning.

First, the project theorizes the production and persistence of knowledge dominance in ways that potentially open it to engagement from traveling practices of sociotechnical knowledge. Second, the project follows dominant attachments of knowledge to personhood, where "personhood" refers to relations within an entity, whether human or nonhuman. Attending to personhood is an important part of an inquiry into knowledge dominance because attaching sociotechnical knowledge poses challenges to those who enact the dominant knowledge form. A third set of practices in critical participation expresses sociotechnical findings as STS sensibilities and adds them to the field, often as gifts. The techniques, devices, infrastructures, and selves that a project offers become *STS practitioners* to the extent they inflect stabilized knowledge forms and practices and, thereby, activate STS analysis.

The course I brought to the teleconference seeks to be an STS practitioner for engineering students, activating STS findings about engineering knowledge and personhood through an experiment in "infrastructuring" (Bowker et al. 2010). It inflects dominant practices of problem-solving and technological design by adding practices of collaborative "problem definition." Adapting the course for an audience of activist educators required working through its three sets of practices.

THEORIZING KNOWLEDGE DOMINANCE FOR TRAVEL

Figure 10.1 shows a faculty image of the mechanical engineering curriculum at Virginia Tech for 2014–2016 graduates. Linked in a one-to-one correspondence are courses from my own curriculum more than forty years earlier. Every university transcript marks a unique trajectory of learning because no two learners pass through exactly the same array of courses, instructors, or learning activities. Also, no two respondents to even a single assignment experience the same configurations of challenges to their knowledge, identities, and commitments.

At the same time, this juxtaposition indexes a remarkable infrastructural connection, a persistent "embeddedness" (Star and Ruhleder 1994, 113; see also Larkin 2013, 336). Both representations prioritize problem-solving practices in discrete but related engineering sciences judged to be the heart of mechanical engineering. And, for the most part, the course titles have not changed. Both curricular infrastructures perform a knowledge form embraced by their builders whose "emergent vocational values" (Jackson and Barbrow 2013, 2873) privilege problem-solving in the engineering sciences to ground technological design. Note how the boxes in the middle of

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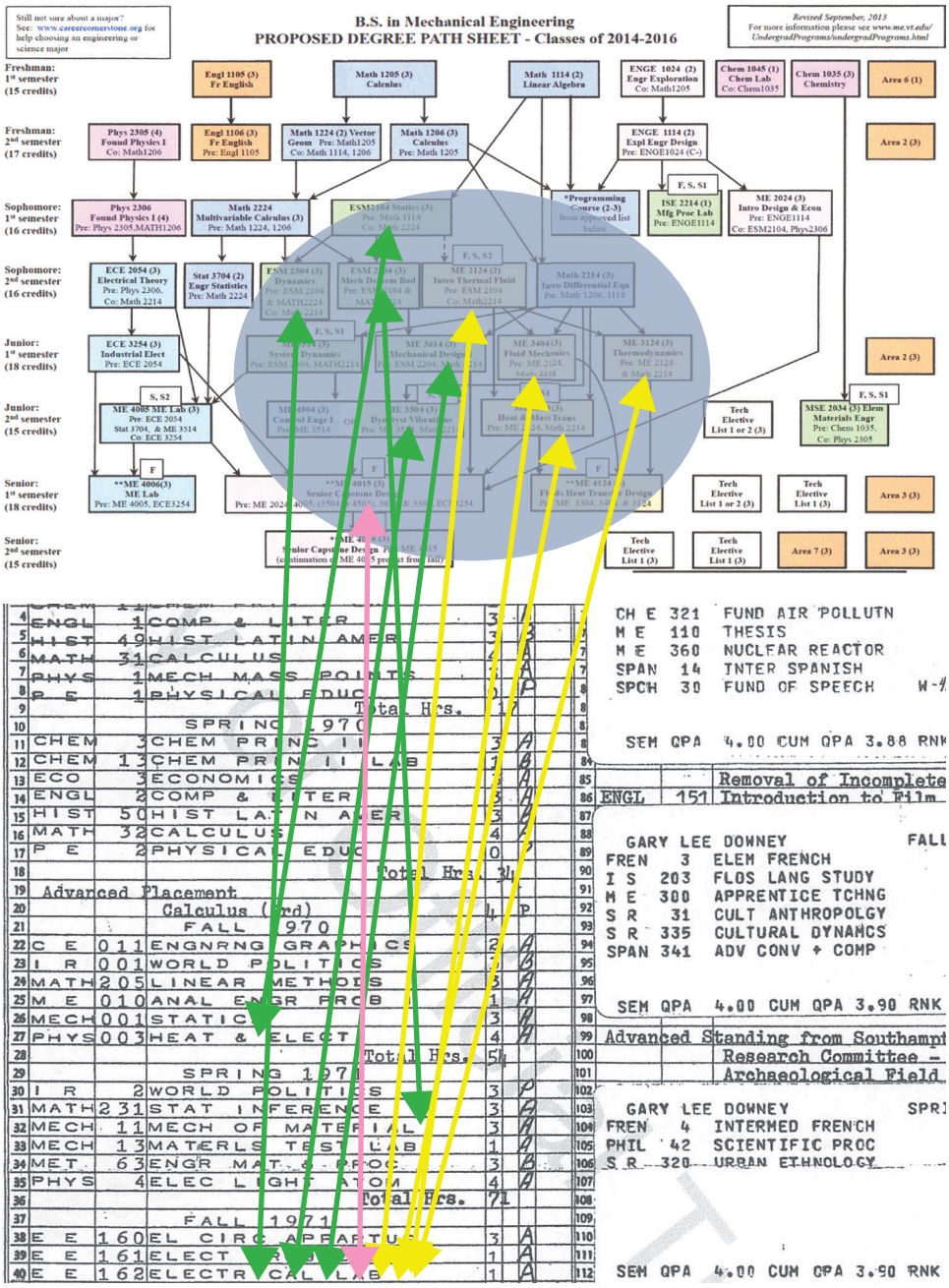
Still not sure about a major?
See: www.careercornerstone.org for help choosing an engineering or science major
B.S. in Mechanical Engineering
PROPOSED DEGREE PATH SHEET - Classes of 2014-2016
Revised September, 2013
For more information please see www.me.vt.edu/UndergradPrograms/undergradPrograms.html
Freshman: 1st semester (15 credits)
Engl 1105 (3) Fr English
Math 1205 (3) Calculus
Math 1114 (2) Linear Algebra
ENGE 1024 (2) Engr Exploration Co: Math1205
Chem 1045 (1) Chem Lab Co: Chem1035
Chem 1035 (3) Chemistry
Area 6 (1)
Freshman: 2nd semester (17 credits)
Phys 2305 (4) Found Physics I Co: Math1206
Engl 1106 (3) Fr English Pre: Engl 1105
Math 1224 (2) Vector Geom Pre: Math1205 Co: Math 1114, 1206
Math 1206 (3) Calculus Pre: Math 1205
ENGE 1114 (2) Expl Engr Design Pre: ENGE1024 (C-)
Area 2 (3)
Sophomore: 1st semester (16 credits)
Phys 2306 Found Physics I (4) Pre: Phys 2305,MATH1206
Math 2224 Multivariable Calculus (3) Pre: Math 1224, 1206
ESM2104 Statics (3) Pre: Math 1114 Co: Math 2224
*Programming Course (2-3) from approved list below
F, S, S1
ISE 2214 (1) Mfg Proc Lab Pre: ENGE1114
ME 2024 (3) Intro Design & Econ Pre: ENGE1114 Co: ESM2104, Phys2306
Sophomore: 2nd semester (16 credits)
ECE 2054 (3) Electrical Theory Pre: Phys 2306, Co: Math 2214
Stat 3704 (2) Engr Statistics Pre: Math 2224
ESM 2304 (3) Dynamics Pre: ESM 2104 & MATH2224 Co: Math 2214
ESM 2124 (3) Mech Deform Bod Pre: ESM 2104 & MATH2224
F, S, S2
ME 2124 (2) Intro Thermal Fluid Pre: ESM 2104 Co: Math2214
Math 2214 (3) Intro Differential Equ Pre: Math 1206, 1114
Junior: 1st semester (18 credits)
ECE 3254 (3) Industrial Elect Pre: ECE 2054
F, S, S1
ME 3614 (3) Mechanical Design I
ME 3404 (3) Fluid Mechanics Pre: ME 2124, Math 2214
ME 3124 (3) Thermodynamics Pre: ME 2124 & Math 2214
Area 2 (3)
Junior: 2nd semester (15 credits)
S, S2
ME 4008 ME Lab (3) Pre: ECE 2054 Stat 3704, & ME 3514 Co: ECE 3254
ME 4504 (3) Control Engr I Pre: ME 3514
ME 3504 (3) Dynamic Sys Vibration Pre: ME 3514, Math 2214
Heat & Mass Trans Pre: ME 2124, Math 2214
Tech Elective List 1 or 2 (3)
F, S, S1
MSE 2034 (3) Elem Materials Engr Pre: Chem 1035, Co: Phys 2305
Senior: 1st semester (18 credits)
F
**ME 4006(3) ME Lab Pre: ME 4005, ECE3254
**ME 4015 (3) Senior Capstone Design Pre: ME 2024, 4005, 3504, 4504, 3614, 3304, ECE 3254
**ME 4124 (3) Fluids Heat Transfer Design Pre: ME 3304, 3404, 3124
Tech Elective List 1 or 2 (3)
Tech Elective List 1 (3)
Area 3 (3)
Senior: 2nd semester (15 credits)
* ME 46 6(3) Senior Capstone Design P ME 45 (continuation of ME 40 5 project from Fall)
Tech Elective List 1 (3)
Tech Elective List 1 (3)
Area 7 (3)
Area 3 (3)

ENGL 1 COMP & LITER
HIST 49 HIST LATIN AMER
MATH 31 CALCULUS
PHYS 1 MECH MASS POINTS
P E 1 PHYSICAL EDUC
Total Hrs.
SPRING 1970
CHEM 3 CHEM PRINC II
CHEM 1 CHEM PRIN II LAB
ECO 3 ECONOMICS
ENGL 2 COMP & LITER
HIST 50 HIST LATIN AMER
MATH 32 CALCULUS
P E 2 PHYSICAL EDUC
Total Hrs.
Advanced Placement
Calculus (Ord)
FALL 970
C E 011 ENGNRNG GRAPHICS
I R 001 WORLD POLITICS
MATH 205 LINEAR METHODS
M E 010 ANAL ENGR PROB
MECH 001 STATIC
PHYS 003 HEAT & ELECT
Total Hrs.
SPRING 1971
I R 2 WORLD POLITICS
MATH 231 STAT INFERENCE
MECH 11 MECH OF MATERIAL
MECH 13 MATERLS TEST LAB
MET 63 ENGR MAT & PROC
PHYS 4 ELEC LIGHT ATOM
Total Hrs.
FALL 1971
E E 160 EL CIRC APPARTUS
E E 161 ELECT
E E 162 ELECTR CAL LAB
CH E 321 FUND AIR POLLUTN
M E 110 THESIS
M E 360 NUCLEAR REACTOR
SPAN 14 INTER SPANISH
SPCH 30 FUND OF SPEECH
SEM GPA 4.00 CUM GPA 3.88 RNK
Removal of Incomplete
ENGL 151 Introduction to Film
GARY LEE DOWNEY FALL
FREN 3 ELEM FRENCH
I S 203 FLOS LANG STUDY
M E 300 APPRENTICE TCHNG
S R 31 CULT ANTHROPOLGY
S R 335 CULTURAL DYNAMCS
SPAN 341 ADV CONV + COMP
SEM GPA 4.00 CUM GPA 3.90 RNK
Advanced Standing from Southampt
Research Committee -
Archaeological Field
GARY LEE DOWNEY SPRI
FREN 4 INTERMED FRENCH
PHIL 42 SCIENTIFIC PROC
S R 320 URBAN ETHNOLOGY
SEM GPA 4.00 CUM GPA 3.90 RNK

10.1 Demarcating technical knowledge from social knowledge in mechanical engineering.

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the faculty image are tightly connected to one another. They depict the core engineering sciences in mechanical engineering. Practices from the basic sciences (boxes at the top) provide supporting inputs, and practices from technical electives (boxes near the bottom) initiate career trajectories. By contrast, practices from the humanities and social sciences (boxes off to the right) are externalized entirely, there to assist only by stabilizing the person.

How we theorize dominant practices in science and technology sets up our movement to engage the field of study. It establishes trajectories for entry and learning, authorizing the attachment of specific types of practices to challenge, disrupt, rupture, or replace what is dominant. It also frames forms of non-knowledge as engaged ignorance—trajectories one is authorized to ignore or destinations one can avoid seeking (cf. Beddoes 2019; Proctor and Schiebinger 2008).

Consider, for example, how approaching science and technology as black boxes to open up has theorized dominance in the lives of facts and artifacts via causal models of scientific and technological advancement (cf. Latour 1987). For science, it is the linear model of knowledge creation–diffusion–utilization. For technology, it is technological determinism. To this day, STS critiques that document sociotechnical contingency, negotiation, context, and openness produce valuable contributions to sociotechnical scholarship for STS audiences. We want to reveal what's inside those boxes. Frequently postponed or left as non-knowledge, however, are potential inquiries into how the ecologies of practices that enact or support the linear model of science or technological determinism might integrate the performance of sociotechnical contingency, negotiation, materiality, and openness into existing practices or not (cf. Wyatt 2008).

These are important issues for arenas that perform demarcation via the causal models. One reflexive challenge that such ecologies pose for the travel of sociotechnical knowledge and sensibilities is to recognize that academic expressions of contingency and so on may be heard by audiences beyond the field as saying only "It's more complex than that." I once heard myself utter versions of that sentence repeatedly in a television discussion about the black box of technological change.

For the scholarship of critique alone, the theoretical issue becomes how best to avoid reductions to causal models. Including the scholarship of travel, however, shifts the standpoint to positions outside the field. The theoretically informed finding of complexity (e.g., as entanglement or multiplicity) can appear to outsiders as a kind of social science black box, one that may not get past the border. After acknowledging complexity, what are people and things to do?

It is worthwhile to take seriously the obvious point that STS sensibilities traveling into the field do not enter a vacuum. All practices for theorizing dominance as sociotechnical in content (e.g., as actor network, system, regime, institution, culture, discourse, hegemony, governmentality, master narrative, ideology, imaginary, knowledge

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hierarchy, structure, or infrastructure) *indicate* both *pathway* and *directionality* as they take on dominant knowledge forms and the ecologies of practices that enact them.

Indicating pathway: Through what practices does the knowledge expressed through this theory of sociotechnical dominance approach the knowledge form it critiques and aspires to supplement or supplant? What trajectories do these expressions track as they emerge and seek attachments to specific people, things, and practices in the empirical arena that compel their attention? In particular, must its scholarship of travel include building an actor network, system, regime, institution, culture, discourse, hegemon, governmentality, master narrative, ideology, imaginary, knowledge hierarchy, structure, infrastructure, or the like? To the extent that theorizing frames its affordances, the answer has to be yes, or at least to include practices along that path.[8]

Indicating directionality: What valences, values, normativities, or ethics does this theory of sociotechnical dominance frame for the expressions that carry it? For audiences that perform demarcation, for example, or even struggle against it, what might it mean it to accept and attempt to integrate our sociotechnical knowledge and practices? In my case, it is important to explore what might make it a welcome thing to integrate into curricular infrastructures explicit attention to the hierarchy between technical knowledge and social knowledge, including the challenges that it poses to engineering students and working engineers. Invoking the geographical metaphor in travel, the analytical task is to sort out the directions that expressions of sociotechnical knowledge might push the dominant demarcation and its practices in order to facilitate learning.

I recognized during a class in the 1980s an opportunity to theorize an engineering knowledge demarcation in a way that might open it to engagement from STS. Engineering students were homogenizing Japanese engineers, construing them as all alike. It was because they shared a culture. We were discussing practices of education and work, not culture. Yet after a while I realized they were explaining education and work in terms of a common popular image of culture that defines it as shared beliefs and values. As shared beliefs and values, culture becomes a kind of container that one is in. Culture is both deeply rooted in persons, akin to the deep structure of a linguistic grammar, and it is set apart from the technical work of engineering.[9]

My theoretical move became calling this popular understanding a gut-level approach to culture—that is, located in the stomach, within the person. I then developed practices to relocate cultural meaning from the stomach to the external environment, the material world. These practices still theorized cultural dominance via a notion of shared meaning, central to culture theory, but with a crucial difference. What was shared was no longer deterministic deep structures shaping persons from within. Shared meaning moved outside to become external images that are observable and contestable and, hence, pose challenges to the person rather than directly shaping them.

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Through this framing, demarcations between technical and social knowledge become *dominant images*—representations that have traveled sufficiently to become given, taken for granted, true, and real for situated arenas of people and things (Downey 2009). Japanese engineers might share challenges to construe their knowledge as, say, in service of the corporate household (extrapolating "*ie*," the samurai family household during the nineteenth century) (Kondo 1990; see also Traweek 1993, 401). But they most certainly also respond in different ways to such practices and expectations. As knowing persons, Japanese engineers are likely no more similar to or different from one another than the engineers around me.

Dominant images of knowledge and knowers are researchable. One starts by asking, "What is an X in science and technology?" For example, a genome, an algorithm, a pandemic virus, or nuclear waste, computer software, or drug regulation? And to whom? Soon one is following the ecology of practices through which nominations of an image achieved material form for audiences in some initial empirical arena, and then traveled sufficiently to become given or taken for granted across other arenas. Or following the practices through which an image experienced shrinkage in acceptance and advocacy and lost its taken-for-granted status. Because the meanings of an image are always specific to audiences that enact it, there is always dominance. "Dominance" refers here to whatever is given to an audience. In this sense, the dominance of an image does not necessarily produce power of someone over someone else; however, such hegemonic power might be an effect of its rise to dominance. At the same time, dominance is always temporary. Linked to situated audiences and arenas, images are never universal nor permanently in place.

A curricular infrastructure and its routine practices offer a good place to query how engineering faculty enact a knowledge form that they take for granted (Star 1999, 378–379) and have decided to share with others. The two infrastructures in figure 10.1 expect students to accept, perform, and value a demarcation between technical and social knowledge. Mathematical calculations in the engineering sciences are at the center, grounding subsequent practices in technology design and development as downstream activities. The basic sciences upstream serve as quasi-consulting operations that sometimes help. All social knowledge of engineering work and its consequences is beyond and supplemental to engineering. For students passing through these infrastructures, acceptance of these powerful definitions and expectations is supposed to be a given. Resistance produces all the effects of an ontological and ethical violation.

Theorizing engineering culture as dominant images indicates initial pathways for sociotechnical travel, at least in principle. While gut-level beliefs and values are hard to change, by definition, shared challenges from external cultural images could be something to engage, contest, inflect, and perhaps, transform. After all, since the dominant image of engineering problem-solving as reported here actually did emerge over time and across space, it too is the outcome of engagements and contestation.

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What then is a "cultural problem" in engineering, as the activist educators put it? A cultural problem appears as persistence of a dominant image (here a knowledge form) in the face of a challenge. It is the challenge that produces the problem, or makes persistence appear to be a problem. It is actually my colleagues' commitment to practices of active learning that makes what they see as transmissionist learning practices appear passive and, hence, a cultural problem. Hmmm, if persistence in learning practices is enacted through a curriculum, then the curriculum has to be a key site, if not *the* key site, for defining and addressing the cultural problem.

Theorizing knowledge dominance as dominant images of engineering and engineers created researchable space between practices of engineering calculation and persons called engineers.[10] It initiated movement into that space. I had been researching how images of engineering and engineers across the world could travel sufficiently to scale up to dominance and become true, be scaled down, be nominated and ascendant, remain marginal, and so on, while always being contested. Seeing knowledge dominance as dominant images generated a challenge to follow would-be knowers as they enter engineering curricula through a range of trajectories, climb through those curricula with unique student trajectories, and then continue to distinct career and life trajectories. Put in more general terms, the move became examining what an infrastructure is to the entities that flow through it, producing "sensorial experiences" (e.g., engineering sensibilities), as they gain knowledge, identities, and commitments (Larkin 2013, 337; cf. Winner 1980)?

A student asked: What's the difference between a dominant image and a stereotype? Remember the engaged ignorance of the black box. What non-knowledge does the concept of dominant image produce, and what can one learn from it? I had already begun advocating that engineering knowers think "dominant image" whenever they hear mention of "culture." Was this pure hubris on my part? After all, Boasian cultural anthropology had required some decades to make the concept of culture travel across American terrain, supplanting evolutionary images of civilization. Well, perhaps not. Experiences of globalization, especially the massive hybridization of circulating identities, may already be repositioning even the popular image of culture as something that can be resisted, refashioned, or repurposed—that is, operating outside the person. I postponed addressing that issue because its temporality and spatiality significantly exceeded my making & doing project. But I couldn't postpone attending to the student's question about stereotype.

I answered by portraying a stereotype as a dominant image in decline. That is, it loses its situated audience through a declining infrastructure or an expanding audience, or both. The adjustment here was to make space in popular realities for dominant image without pushing or redirecting stereotype—I see no stakes there. I illustrated by calling attention to the image of a woman as inherently emotional, unlike a man. For my mother, the image was simply true, a dominant image. She repeatedly told me she would never vote for a woman because "they're too bitchy."

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Yet during my lifetime, the women's movement had undermined infrastructural support for the image while expanding its public audience to include more women, shrinking it to a stereotype. The image remains an accusation that has continued to decline in force but has not disappeared—yet.

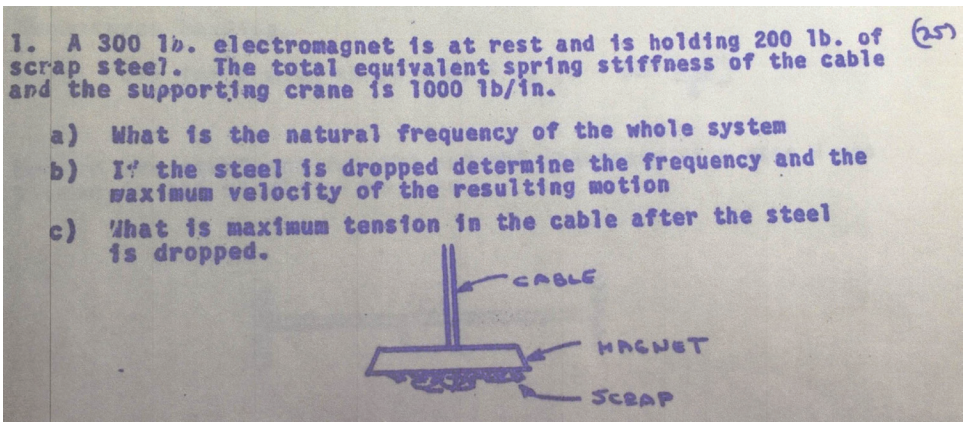
Theorizing knowledge dominance for travel initiates movement by indicating pathway and directionality. Our answers to the question "What is an X in science and technology?" become nominations that seek the status of dominant knowledge forms. Taking account of and responsibility for the pathway and directionality of the STS knowledge we produce also includes attending to its non-knowledge. My main challenge going into the teleconference was to figure out how to inflect their assumption that culture lay outside the curriculum, perhaps repositioning it as a dominant image in decline.

FOLLOWING KNOWLEDGE TO PERSONHOOD

Adding travel to STS critique of a dominant knowledge form reveals it to be a knowledge-knower hierarchy (Nieusma 2007). Critically participating in it quickly becomes a problem of personhood.

Figure 10.2 offers an example of a problem in engineering vibrations I completed as a student. It tested my ability to predict the behavior of an electromagnet holding a pile of scrap metal and suspended on a cable. With my theoretical knowledge of engineering vibrations and specific information about the objects, I could calculate how much the magnet would tend to bounce up and down on the cable and what would happen to the cable if the magnet suddenly dropped the scrap.

I like this problem. The challenges it posed to me as a learner were clear. My proposed answers were either right or wrong. If wrong, I remained an outsider to this knowledge, powerless to mobilize it. If right, I successfully demonstrated a level of


1. A 300 lb. electromagnet is at rest and is holding 200 lb. of scrap steel. The total equivalent spring stiffness of the cable and the supporting crane is 1000 lb/in.
(25)
a) What is the natural frequency of the whole system
b) If the steel is dropped determine the frequency and the maximum velocity of the resulting motion
c) What is maximum tension in the cable after the steel is dropped.
CABLE
MAGNET
SCRAP

10.2 Performing right and wrong.

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engineering competence that I could bring to more complex problems. At the same time, I added an identity and accepted a commitment to achieve "optimal gain" (Alder 1997, 60) in engineering design. The identity added new relations with other entities, and the commitment added direction. I could set off, for example, to make a lighter magnet.

Accepting and performing the practices that support and enact a knowledge demarcation ascribes one status, authority, and directionality in an associated hierarchy of persons.[11] Engineering students spend years solving hundreds, if not thousands, of problems in just this way. Carrying such knowledge practices forward in their careers makes them performative (Callon 1998) in ecologies of engineering work. Knowers of engineering problem-solving can be confident of their identities in relation to other contributors to technological development, especially to those who claim nonengineering knowledge about the human or social dimensions of engineering. In the simplest, crudest case, if you and I are working together to solve an engineering problem and I know I am right, you had better agree with me or you are clearly wrong. Extrapolated more generally, accept my practices of calculation and the bridge will stand, benefiting all; resist them and it will fall, hurting many. The dominant image of engineering problem-solving grants engineers an exclusive jurisdiction (Abbott 1988) over technological development and authorizes a commitment to omnibenevolence as a directional outcome carrying ethical force. Engineering helps everyone.[12]

Critique of a knowledge form that attends to travel becomes an issue of personhood for its knowers. Consider advocacy for active learning, for example, via practices of problem-based learning, project-based learning, collaborative learning, flipped classrooms, think-pair-share, journaling, and so on. Judged from the persistent reality of engineering calculation, active learning can appear to require an awful lot of talking. Might there be reason for concern among engineers that such practices could actually undermine the reassuring clarity of engineering competence and decision-making? Perhaps they risk degrading it into something approaching irrelevant conversation (i.e., the humanities and social sciences). Following knowledge to personhood, advocates of active learning have to figure out not only how its practices inflect engineering learning but also how those practices reframe the figure of the engineer itself. The dominant figure at present leads through calculation, not talk.

Following knowledge to personhood in the scholarship of travel applies reflexively to the person of the STS scholar as well. One's identity as a sociotechnical knower becomes a salient issue in the potential attachment and integration of one's knowledge in a dominant knowledge ecology. It is likely more difficult, for example, for one to critically inflect a knowledge demarcation if it defines one as a non-knower at the outset. On what grounds does one gain credibility or trust? And whom does one have to become in order to participate? My achieved status as a degreed mechanical

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engineer granted me preliminary security clearance as a knower among performers of engineering problem-solving. But who is this Downey person really? Perhaps his graduate training in cultural anthropology and career commitment to STS scholarship actually reveal that he is not now and never really was an engineer. He was but a tourist in engineering, passing through to take in the sights. Or perhaps he defected later, taken in and misled by the non-knowledge that is the social sciences.[13]

In any case, if engineers treat culture as outside of engineering, then inviting Downey to help them change the culture is an invitation to an outsider. It becomes his job to show that his knowledge and his person can fit within engineering. His degree appears to help. But he must also ask: Can he retain his identity as a sociotechnical scholar and commitment to producing and expressing sociotechnical knowledge to effect learning? Including travel in STS scholarship challenges him to follow, judge, and assess in every interaction not only whom he wants them to become but also whom and what sorts of directions he must consider accepting for himself.

During the teleconference, I failed to adapt this problem of knowledge and personhood for practitioners of active learning. That is, I did not offer any indications for how to use my cultural knowledge to retheorize themselves as knowers of culture within engineering who are also committed to practices of active learning. I had offered examples of how curricular infrastructures link dominant knowledge practices to associated identities and commitments (more on this below), and that follow-up email had suggested acceptance of the argument. But the draft position statement made clear that the exchange had not produced participation for me in collaboration with them. The statement restored clarity and security for them as engineers by once again externalizing culture, and me with it.

The draft statement did offer an opening. It construed culture not as bedrock beliefs and values, as my students had done, but as "attitudes, behaviors, and motivations" that together comprise "mindsets" (Buffinton et al. 2017). I resist the term "mind-sets." It reinscribes a mind-body distinction that sociotechnical learning challenges. It privileges a mind that is difficult to observe and detaches material practices, such as analyzing an electromagnet on a cable or passing through a curricular infrastructure. However, construing culture as mind-sets does pull it up from the gut and make it a changeable phenomenon. To advocates of active learning, the cultural problem in engineering becomes a solvable problem. It morphs into a challenge to add new mind-sets without diminishing competencies in engineering problem-solving.

I saw in this language a new pathway for critical participation and elected to experiment with it. I tried positioning the learning practices I had offered in the workshop as an approach to changing mind-sets. I suggested that practices aimed at mind-sets could begin to address cultural challenges that are embedded in infrastructures of engineering formation and work. A key practice to add is to critically examine the knowledge, identities, and commitments one is expected to value when participating

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in such infrastructures. I was experimenting with pathway but had a sinking feeling about indicating directionality. What directionalities come with picturing culture change through mind-sets? Was I accepting a move that would once again locate culture outside engineering, and me with it?

ADDING AND TRACKING ALTERNATES

This concern about externalizing myself was a familiar one, a recurring source of anxiety and analytic attention. Earlier in my career, I had experimented with controversy studies to bring sociotechnical knowledge to engineering students. To contest a performative expectation that they might have to divide worlds of work into two parts, right and wrong,[14] I asked them to role-play diverse participants in technological controversies. They adopted a range of sociopolitical identities and commitments, composed and debated what they judged to be defensible knowledge claims, and analyzed outcomes.

Unfortunately, the effort did not critically engage the students, as I understood it. I was not offering practices that they could carry back to their engineering science courses and inflect what they were gaining there. Their experiences with me were recess, leisure, escape, tourism in STS. I was effectively treating them as mini-first-year STS graduate students, trying to reproduce myself in them. I provided no tools to become critical analysts of their own knowledge, identities, and commitments as engineers. Students gave me high ratings and I gained a reputation as a strong teacher. My main reaction was depression about these outcomes.

We cannot expect interlocutors in technoscience to willingly inflect their own knowledge and put at risk persistent identities and commitments, especially when these appear in multiple, distributed ecologies of performance, such as in schools and at work. When sociotechnical critique includes travel, it recognizes itself as indicating alternate techniques, devices, infrastructures and selves, and charges itself to critically examine their attachments and integration as they seek to facilitate learning. Distinct alternates may indicate dramatically different temporalities and spatialities for inflecting dominant knowledge practices (Shapiro, Zakariya, and Roberts 2017; and Shapiro, demo account 8 in this volume).

One way to identify potential attachments and sort out their inflections is to direct critical attention to frictions in existing relations between knowledge and person—that is, places where personhood loses its smoothness and becomes multiple (Kember 2003). If we follow engineering learning to engineering work through the preceding account of problem-solving and personhood, we quickly encounter two remarkable frictions. First, engineers always work with diverse knowers who bring distinct compositions of knowledge, identity, and commitment. Any attempt to divide them into two groups will likely appear naïve. It can lead to blindness to differences and nonsensical outcomes in how engineers approach and interact with others. Disagreement need not make others wrong.

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Second, whereas problems in school are largely given, problems at work are largely not. Engineers who expect to be given problems, or just wait for them, can have difficulty asserting their agencies in technological development and other engineering work. Technology work today includes many fields that portray technology as ubiquitous and claim some kind of jurisdiction in its development. In addition, social studies of technology have long made clear that engineers never really had sole jurisdiction over technological development in the first place (Suchman 2000).

The implication is that to continue defining engineering knowledge and personhood around right/wrong problem-solving risks accepting the futility of hoped-for leadership and embracing a stripped-down vision of technical support.[15] Engineering calculation remains valuable but subordinated below decision-making performed by others. Engineering practice becomes self-limiting, with its claim to benefiting all a delusion.

Frictions between knowledge and person can indicate promising "entry point[s]" (Jackson and Buyuktur 2014, 305) for sociotechnical learning. I asked: Do existing curricula expect engineers to accept any knowers who differ from them but still have knowledge and value? Yes, other engineers! Diversity in workplaces includes differences among engineers, yet the dominant image of engineering offers no account of such differences. Engineers certainly have accounts of one another as persons, but complimentary accounts fit the dominant image and disparaging accounts fall better into the category of stereotype (Riley 2008; Tonso 2007).

The STS practitioner I adapted for the teleconference took these two frictions as entry points for infrastructuring. The course's main narrative describes would-be engineers in different countries as flowing through emergent, situated learning infrastructures, which challenge them to accept stabilized compositions of knowledge, identities, and commitments. The pursuit of optimal material gain for all through calculation is a recurring ethical commitment, yet its specificities vary significantly across these infrastructures and over time. In some places it's about achieving distance from manual labor (United Kingdom), whereas in others it's about advancing society toward imagined perfection (France), maximizing low-cost production for mass consumption (United States), catching up with others (Korea), and so on (Downey and Lucena 2004; Smith 2019). Engineers and engineering are already more than one thing, with localized forms of technical knowledge that include localized forms of social knowledge.

The key attachment in the course inflects engineering problem-solving by adding sociotechnical practices for defining problems in collaboration with diverse others (framed as PDS, or engineering as problem definition and solution). PDS practices prioritize listening for evidence of distinct knowledge, identities, and commitments and then collaborating to accommodate those differences in defining and solving workplace problems (Downey 2008; cf. Lucena, Schneider, and Leydens 2010). Students add to mathematical calculation a method called "Location, Knowledge, and Desire," which asks: How are engineers and others located? What do they know?

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What do they want? And how can I adapt my definition of the problem to take account of other definitions?

The directionalities that PDS practices indicate aim to help engineers stay at the table, participating in decision-making contexts amid others who also have knowledge and value. Positioning these practices as additions takes advantage of the fact that self-styled problem-solving engineers do not dismiss problem definition as irrelevant to engineering. They locate it upstream of problem-solving. Its practices are not foreign or alien, just largely unanalyzed. The dominant image of engineering is not destroyed or replaced, but is inflected in a way that expands in scope and importance: engineering becomes collaborative problem definition and solution. When students accept this learning, they also revalue engineering leadership as technical mediation amid diverse knowers. They may still embrace the claimed jurisdiction over technological design, but their identities are no longer at risk when they find out that most engineering jobs do not include design (Russell and Vinsel 2019).

The travel of alternates through empirical arenas produces *personal geographies* along the way. A personal geography is a narrative map of a trajectory, tracking how an entity (e.g., a human person or other agent) adds identities and inflects its personhood through movements and encounters with others (Downey 2011a, 8–14). It contrasts with the *project history* and the *autobiography*, which tend to double as description and promotion. The personal geography accepts responsibility to account for others that interact with the entity at stake, adding identities themselves in the process, and to recognize those people, things, and practices left untouched. The personal geography of an STS practitioner follows how it produces flows of sociotechnical learning within its field of study and back again to STS, or not, and with what specific temporalities and spatialities. Of particular concern is whether its expressions of STS knowledge attach, inflect, and persist.

The STS practitioner at issue here—the elective course—began as a short-term, wholly local initiative that seeks entry into the curricular infrastructure from a specific location on the margins where I hold a measure of jurisdiction. In figure 10.1 it is an orange box to the right, connected to nothing. Its practices attach only to those students who seek it out. Its personal geography tracks other pathways I have explored thus far, including consulting with working engineers to attach it to their work, workshops for educators and administrators, the production of video and other multimedia content and its distribution on YouTube, and books for engineering audiences that may not otherwise value reading. Each of these alternates has trekked around the engineering science curriculum but not reached deeply into it.

One source of overt resistance to this STS practitioner has been to adding technical mediation to the dominant image of engineering leadership. The technical mediator indicated by this framing still insists on problem-solving calculation as integral to engineering decision-making but also listens, taking responsibility to reconcile competing definitions of the issues and problems at hand from both engineers and

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nonengineers. During a question-and-answer period at Stanford University in the heart of Silicon Valley, a senior engineer saw in this image a demotion: "I don't think engineers at this university aspire to be mediators." The STS practitioner had run into another knowledge demarcation through which engineers privilege engineering design as central to innovation (Wisnioski, Hintz, and Kleine 2019).

A key goal in sharing the course with advocates of active learning was to see if their project might add a pathway to inflect core practices of engineering calculation. Actually sharing it with them, however, produced a very different outcome. The exchange made clear that my project in STS making & doing does not stand alone and that the travel of its knowledge depends on recognizing itself as such. The ecologies of dominant practices in engineering include a multitude of other scholarly projects that aim to inflect them and whose provocations and challenges may overlap with one another. How they do or do not do so warrants explicit and detailed attention in the scholarship of travel.

Consider scholarly projects to make more central the practices of communication, diversity, social justice, teamwork, globalization, supply chains, social context, development, creativity, design, maintenance, anti-racism, and so on. Tracking the alternates that one project indicates must recognize and take account of interactions with the personal geographies of other alternates. Particularly important for projects expressing STS knowledge are other STS projects that identify and respond to different frictions. For example, adding collaborative problem definition to problem-solving in engineering has the effect of leaving largely in place existing practices of mathematical problem-solving, at least for the short term. There is certainly reason to critically engage the heart of engineering problem-solving now. Considerable evidence exists, for example, that following rigor in engineering calculation to its knowers offers insights into how engineers in the United States became and remain predominantly male and white (Oldenziel 1999; Riley 2017; Slaton 2010). Beyond that, even solving the single vibrations problem in figure 10.2 commits one to support a working world that includes a steel industry and the manufacture of cable and electromagnets (Noble 1977). Also, STS scholars whose projects commit to social justice have told me that the image of problem definition and solution does not address power relations sufficiently for them. Calling attention to temporality, I have maintained that reframing engineering as problem definition and solution takes a step that is both potentially realizable and necessary even to pursue the long-term goal of reducing the extent to which engineering practices produce injustice. Yet I cannot know for sure.

Differences such as these in the STS scholarship of travel are all researchable, with each potentially informing the other. Just as critically engaging a dominant knowledge form calls attention to specific practices that enact and support it, so does it also direct attention to how the specificities of different projects engage and interact with one another. It is important to explore whether and how distinct projects may

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prove to be complementary or facilitate new iterations that combine two or more projects together. This is a key way that assessing STS scholarship from the outside in distinguishes critical participation from critique alone. Every project that takes on dominant knowledge practices emerges in the midst of potential collaborators that might engage one another, and the practices of collaboration become a key problem space. The epistemic significance of such practices extends them far beyond what critique might dismiss as mere collegiality. Indeed, collaboration in the scholarship of travel is a sign of strength because it signals a vision of the field as a whole. This project has made it my job, for example, to critically examine how Engineering Cultures might be conceived as enacting practices of active learning.

It is also important for every project in a given empirical arena to recognize that persistence is also travel, with analyzable personal geographies. The curricular infrastructures of engineering are changing all the time, as advocates make adjustments to their contents to increase performance, albeit often in existing dominant terms. Biology, for example, has gained standing alongside physics and chemistry as providing valuable inputs into engineering calculation. The contents of every discipline and field have gone digital, giving the appearance that engineering has become "applied information technology" (Williams 2002, 46). Engineering mechanics is in clear decline. Engineering science faculty who struggle to position changing interests within a curriculum routinely respond to experiments elevating external, subordinated knowledge with the question, What do you want us to drop?

The scholars of active learning who contacted me insist that its practices help learners better understand and articulate both what they know and what they don't—that is, to reflect critically on their learning. Neither before nor during the teleconference did it occur to me to go beyond advocating for my STS practitioner (a default practice in scholarship) to figuring out and sharing how they might integrate the sociotechnical learning in Engineering Cultures as active learning or figuring out how their project might inflect mine. I stopped doing critical participation with them. Only while producing this demo account did I ask how my project might become a traveling companion with this one and others. Tracking the trajectories of different projects in relation to one another is a key practice in the scholarship of travel.

The teleconference and subsequent exchanges with activist educators looking to change mind-sets taught me three things. First, the engineering demarcation between technical and social knowledge remains a remarkably resilient image that flourishes in robust ecologies of performance. Even engineering educators who seek to reframe core learning in ways that might help students reflect critically on that learning can find themselves defaulting to that demarcation. The resistance they seek to overcome lies in their practices, too. Attaching my revised image of culture produced an inflection in how they presented active learning but it did not join with them to take on the dominant demarcation itself.

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Second, my project has allies. Working as an individual scholar, I have sought to express STS and other knowledge in ways that might attach to and inflect a dominant knowledge form. Yet my project also gains meaning and significance in relation to other such projects. Viewed through the active learning project, mine appears to be contributing to an epistemic coalition of practices that are traveling together and can learn much from one another.

Third, my project needs another point of entry to the engineering science curriculum. Might it be advisable to locate this learning at the top of the curriculum rather than, or in addition to, the side? In other words, at the beginning, as a kind of pre-engineering or early engineering input? In the above analysis, the self-limiting cultural problem in engineering lives in practices at the infrastructural center. Adding knowledge to inflect it has to be more than elective knowledge. Engineering students might find it instructive to learn at the outset that their own formation is a spatially and temporally specific emergence. Might those who learn to see themselves as situated actors be prepared to carry that knowledge to the engineering sciences, revaluing them as key sources of knowledge but only part of what competent engineers need to know to work effectively with others?

Gee, that textbook I have been drafting just got shorter. If it is to infrastructure from the top, it must not only seek overlap with attachments produced by other projects, both sociotechnical and otherwise. It must also find a place alongside other learning activities and resources that already reside there. That likely means enabling students to get through it in a couple of weeks.

CONCLUSION: WHEN STS CRITIQUE INCLUDES TRAVEL

Here's the draft text I received. Although it accepted the practice of critical reflection from the teleconference, it maintained the demarcation between technical and social by locating technical engineering within culture. Yet by framing culture through mind-set, might it introduce the possibility of change?

> We are all contributors to an ecosystem (academics, non-academics, professional societies, etc.) that is having limited success in creating the desired culture, climate, and educational outcomes. This is a problem not of content, data, or rational arguments but rather, as cultural anthropologist Prof. Gary Downey at Virginia Tech pointed out to conference organizers, the need to consider the way in which change takes place within an established culture. A change in culture requires a change in mindset, often through a personal experiential transformation. To begin this transformation, faculty need to encourage students to reflect on knowledge, identity, and commitment. We need to do so not only because employers and students themselves will demand it, but moreover as part of our responsibility as 21st century educators.

My version in response relocated culture within technical engineering. By accepting mind-set as a pathway to culture change, it affirmed the value of critical reflection.

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It also indicated infrastructures as sites for inflecting engineering knowledge. It fell short, however, of taking the next steps: attaching the image of engineering as problem definition and solution to practices of active learning and inflecting the image through those practices:

> We are all contributors to an ecosystem (academics, non-academics, professional societies, etc.) that is having limited success in creating more desirable climates and educational outcomes. This is a problem not only of content, data, or rational arguments narrowly construed, but rather, as cultural anthropologist Prof. Gary Downey at Virginia Tech pointed out to conference organizers, the need to consider the ways existing infrastructures of engineering formation and work have emerged and pose powerful cultural challenges. Changes in culture can begin with changes in mindsets, including through personal experiential transformation. One way to start is for both faculty and students to reflect on the knowledge, identities, and commitments they value, or feel expected to value. We educators need to lead such reflection not only because employers and students themselves will demand it, but also as part of our pedagogical responsibilities in the 21st century.

Critical STS analysis makes visible sociotechnical contents that dominant knowledge forms hide. The continued contribution of critical STS to the social sciences and humanities has become increasingly important because disciplinary scholarship in these fields has come to treat technology as ubiquitous. They claim jurisdiction over what they see as the human dimensions or impacts of technologies. In the process, they miss the crucial STS finding and insight that the so-called social or nontechnical dimensions of issues involving science and technology always relate to the so-called knowledge or technical dimensions. Thus, they inhibit themselves from even seeking to attach their knowledge to the empirical fields they study, let alone indicating pathways and directionalities.

STS scholarship must include recognizing and analyzing how sociotechnical knowledge might travel, critically engaging dominant knowledge forms and producing learning beyond the boundaries of the field. Each of our critiques bites off and problematizes some small bits of given knowledge realities, nominating new realities. Critically engaging dominant knowledge forms through their ecologies of performance—even via a single paragraph—challenges us as sociotechnical scholars to express STS knowledge through technique, devices, infrastructures, and selves while also recognizing and trying to learn from the silences that our practices produce.

In the face of resilient knowledge forms, sociotechnical critiques that compete with one another to diagnose well remain essential. Sociotechnical critique itself is warranted as long as knowledge forms in technoscience demarcate technical from social. Yet the scholarship of sociotechnical travel is equally essential. Without scholarly attention to critical engagement and flows of sociotechnical learning, critique can languish as disciplinary celebrations of intellectual virtuosity. Such celebration carries status and visibility within the conference hotel. Adding the scholarship of sociotechnical travel fixes the gaze of critique on the trajectories of sociotechnical knowledge and sensibilities outside the hotel.

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Critical participation positions the critical analysis of dominant knowledge forms on learner-oriented pathways. Practices to theorize knowledge dominance, follow knowledge to personhood, and attach alternates all involve examining and assessing our knowledge from positions outside the field. Foregrounding the issue of travel within STS scholarship can increase its chances of actually inflecting dominant knowledge forms beyond the boundaries of the field, but only to the extent we remain open to reflexive learning from those whom we purport to teach. A great virtue of the scholarship of travel is that it is rarely a zero-sum scholarly game. Our external projects compete with one another for position and resources, but one does not have to lose for another to win. Critical participation cannot be done alone. And it rarely can be done quickly.

ACKNOWLEDGMENTS

Thanks so much to Keith Buffinton, Vincent Manno, and Rick Vaz for inviting me to participate critically in their efforts to expand active learning in engineering. Many thanks to Torben Jensen, Nicholas Shapiro, Jessica Smith, Hu Ke, Laura Lane, Annie Patrick, Benjamin Cohen, Lee Vinsel, and a helpful external reviewer for critical commentary and valuable suggestions on this demo account. I greatly appreciate ongoing conversations with Matthew Wisnioski about STS and engineering education. Thanks to Teun Zuiderent-Jerak for informed and generous critical collegiality that provoked me to sharpen and clarify.

NOTES

1. Email from Rick Vaz, Worcester Polytechnic Institute, April 3, 2017. Cited with permission.

2. I view STS as an interdisciplinary field that critically analyzes and reframes relations among science, technology, and society.

3. See for example Adams et al. (2007); Alder (1997); Bucciarelli (1994); Downey (1998); Faulkner (2007); Layton (1971); Lucena (2005); Seely (1999); Slaton (2010); Vinck and Blanco (2003); Williams (2002); and Wisnioski (2012).

4. See Buffinton et al. (2017), 11. I was contacted by Keith Buffinton, then professor of mechanical engineering and soon-to-be interim dean of the College of Engineering at Bucknell University, and Vincent Manno, then provost of the Franklin W. Olin College of Engineering. Cited with permission.

5. In the introduction to this volume, Downey and Zuiderent-Jerak define STS sensibilities as "observable instances of knowledge expression that enact STS knowledge contents but without necessary reference to their formal linguistic formulations"—for example, techniques, devices, infrastructures, and selves. See Jensen (2007) for a related analysis of knowledge attachments.

6. Much work in the interdisciplinary field of engineering studies makes similar arguments. For bibliographic starting points, see publications in *Engineering Studies: Journal of the International Network for Engineering Studies*. The significance of this overlap for inflecting dominant knowledge practices emerges below.

7. I gratefully acknowledge the contributions of nearly fifty STS graduate assistants, other graduate students, and faculty who have made substantial contributions to the course as well

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as developed and taught their own versions or extensions of it, beginning with Juan Lucena in Spring 1995 (see Downey 2011b).

8. Such building is not the "prescriptive description" in "constitutionalism" that John Law describes, which is a linear model exercise. It necessarily includes "interference" (Law 2010).

9. Traweek (1988, 162) calls a similar distinction in physics a "culture of no culture."

10. Outcomes of engineering work also became newly interesting via the question "Who's in those technologies?" Dominant images of technologies have audiences, too.

11. It is important to examine and track the whole ecology of practices that enact and support a dominant knowledge form because an STS project to inflect it may produce traceable interactions with some or all of those practices. In this project, relevant practices include inter alia the curricular and extracurricular practices of students, the diverse activities of faculty, specificities in courses and fields, work-life relations and interactions, links to professional organizations, employment expos, and so on.

12. Thanks to Marie Stettler Kleine for calling my attention to "omnibenevolence" to describe the normative commitment built into achieving optimal gain through engineering problem-solving. It is better than "normative holism," which I have also used. See also Jessica Smith's (2019, 2021) framing of this commitment as an "ethic of material provisioning." It carries the twin benefits of clearly locating the commitment in the material world and critically participating in the engineers' existing commitment to engineering ethics.

13. Confronting this issue of personhood actually led me to shift my theoretical framing of socio-technical travel itself from intervention (Downey and Dumit 1997) to critical participation. I came to see intervention as indicating practices in which my primary subject-object position as knower remains outside of the empirical field. I intervene from outside with some measure of safety for my STS personhood and scholarship. By contrast, doing critical participation indicates that my scholarship seeks and accepts an additional subject-object position within engineering, if only for the duration of the project. Intervention becomes critical participation when it recognizes its accountability to the empirical arena it engages (see Liboiron et al., demo account 6 in this volume).

14. See Brody (1992) for an example of this tendency in John Sununu, former chief of staff to US president George H. W. Bush.

15. Another knowledge demarcation to inflect in engineering distinguishes engineering leadership from technical support, once again by privileging problem-solving practices in the engineering sciences (Russell and Vinsel 2019; Slaton 2010). Practices of critical participation in the technical-social and leadership-support demarcations may well overlap with one another to a significant extent. More on this below.

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CODA

Infrastructuring STS Making & Doing

Gary Lee Downey and Teun Zuiderent-Jerak

"I wasn't aware she was doing all this work," said a senior colleague about the demo by a PhD student from the same department. "I only knew about the paper presentation."

"I needed the paper to get my travel funded," the junior colleague commented, "but I'm really here for this program!"

At a table across the room, Jennifer Henderson (University of Colorado, Boulder) asked, "How do I claim credit for this?" She was demoing a data self-visualization of her physical movements as a research scholar in meteorology and weather forecasting who helps "identify and address issues of urgent concern for those in harm's way." Employed in a position that rewards published research in refereed, indexed journals, Henderson was doubtful that she could continue allocating travel funds to demonstrate a reflexive self-inquiry that she could claim only as a conference presentation.[1]

These scholars were demoing projects in the fourth STS Making & Doing program at the 2019 annual meeting of the Society for Social Studies of Science (4S) in New Orleans. The mismatch between the enthusiasm and commitment that has filled the room in these sessions and the functional invisibility (Star and Strauss 1999) of making & doing scholarship outside them had quickly become a recurrent topic of conversation among participants and attendees at these programs. The invisibility and lack of status that produced it made some participants, especially those in less secure positions, wonder if they would be able to carry on their projects. And as the demo accounts in this book show, the scholarship of STS making & doing often requires practices to develop over extended periods of time.

The tension between experimenting with practices of STS making & doing and needing to secure visible credit for one's scholarly activities also came up at the panel discussion that followed. "If this work goes to waste," said panelist Fernando Dominguez Rubio (University of California, San Diego), "it is such a huge loss." Projects in STS making & doing are a "huge time suck," he pointed out, yet "criteria are missing"

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for assessing their practices. Panel members agreed that building the scholarship of STS making & doing has to include figuring out how to claim credit for it. "We are the ones setting those criteria," Dominguez Rubio added, referring to attendees at the meeting. "That work starts with us, not with academia [in general]."[2] Subsequent conversation among panelists and audience members wrestled with such questions as how projects presented at such meetings, and having digital presences at the STS Making & Doing pages of the 4S website,[3] might be able to get DOIs (digital object identifiers), a recognized marker of archival publication, and how accounts of practices of STS making & doing might warrant publication in one or more STS journals.

This concluding coda extends the conversation by opening up the question of credit and visibility in light of the demo accounts in this book. A number of practices have already contributed to infrastructuring the scholarship of STS making & doing. Formulating and enacting those practices in the context of academic regimes of valuation has infused them with academic judgments and criteria of assessment, both explicit and implicit. We therefore begin by critically reflecting on the practices through which STS making & doing has joined and then become a recurring program at 4S annual meetings.

The framing of this book itself addresses the issue of publication. As we outline in the introduction, its ten demo accounts document the specific practices through which their projects (1) express STS knowledge for other audiences and settings, (2) produce travel for STS knowledge into and across the empirical field, (3) make the scholar visible in the scholarly practices, and (4) facilitate learning on the part of the STS scholars involved. These practices are both distinguishable and analyzable, and potentially ground criteria for assessing demo accounts of STS making & doing and claiming credit for them as publishable STS scholarship. The introduction shows that flows of STS knowledge into and out from empirical arenas tend to take place through *STS sensibilities* (i.e., observable instances of knowledge expression that enact STS knowledge contents but without necessary reference to their formal linguistic formulations). Extending that analysis, this coda concludes with a brief experiment that draws on the demo accounts to frame criteria that might help inform the further publication of projects and practices of STS making & doing.

PULLING THIS SCHOLARSHIP INSIDE

The first move to colocate a wide range of STS making & doing projects came at the 2014 joint meeting of ESOCITE and 4S in Buenos Aires, which brought together STS scholars from the Global South and Global North.[4] Titled "What Is STS For? What Are STS Scholars For? Making & Doing in Science and Technology Studies" (with equivalent titles in Spanish and Portuguese), the opening plenary session was convened by two presidents[5] who invited twenty-four scholars to deliver three-minute presentations about their projects in STS making & doing. They did do so in three

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languages and with translated text displayed on two large screens. Presenters affiliated with institutions in Argentina, Brazil, Chile, Colombia, Costa Rica, Denmark, Japan, Mexico, the Netherlands, Sweden, Taiwan, the United Kingdom, the United States, Uruguay, and Venezuela.

As an infrastructural practice, the presidential plenary nominates an arena of scholarship as emergent and deserving of focused attention. It infrastructures through juxtaposition, mobilizing the symbolic capital of the organizers to pull that scholarship into the meeting in a prominent position alongside and equal to the paper sessions that follow. In this case, STS scholarship in Latin America had long called attention to the political dimensions of issues in science, technology, and medicine to a greater extent than scholarship in the Global North (Kreimer and Vessuri 2018). An opening plenary examining the for-what and for-whom in STS projects that purposely extended beyond the academic article or book could make visible the overlaps between emerging scholarship in both Global South and Global North that might otherwise remain hidden or unanalyzed during the meeting.

In addition, bringing together twenty-four scholars at different career stages who made projects in STS making & doing integral to their scholarship would make it difficult to discount the core intellectual claim in the event—it enacted a moment of recognition that was long overdue. For the scholars involved, the gathering could become a generative meetup. Each project would gain the visibility of a plenary presentation. Three minutes might be sufficient for attendees to find resonances with presented projects and then seek conversations and, perhaps, collaborations that would pull practices of STS making & doing deeper into the meeting and help entwine the two societies together. And presenting in rapid succession would produce the collective assertion that making & doing is a constitutive and promising contributor to the scholarship of STS.

For practices of STS making & doing to claim to be a thing for STS scholars, they had to find their way into an existing scholarly infrastructure. A joint scholarly meeting that was already launching itself into the unknown by bringing together scholarly initiatives from the Global South and the Global North provided a good occasion to pull STS making & doing into a privileged scholarly space. Presidencies are short-lived, however, and the nominations in an opening plenary might not find ways to attach to existing practices. For the scholarship of STS making & doing to move beyond claiming to be a thing and actually become a thing alongside research-only scholarship, the juxtaposition would have to extend to other scholarly infrastructures.[6]

ATTACHING A PROGRAM

The 4S Council formalized another juxtaposition when it voted unanimously to define STS making & doing as a scholarly initiative.[7] Proposed by an ad hoc committee

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convened for this purpose and following comments from the membership, the council materialized a standing infrastructure—a meeting program designed to authorize and support project demonstrations. Attaching a program to the meeting infrastructure would enable members to share "scholarly practices of participation, engagement, and intervention in their fields of study." The specific scholarly objectives included "improv[ing] the effectiveness and influence of STS scholarship beyond the field," described here as practices of knowledge expression and knowledge travel, and "expand[ing] the modes of STS knowledge production," described here as facilitating learning on the part of STS scholars (Amir et al. 2014, 3).[8]

Demonstrations of STS making & doing took the form of a meeting session with projects distributed across a large room for four or five hours. Presenters gained webspace prior to the meeting to inform and attract audiences and then conducted demonstrations from tables equipped with nothing more than power supply. The open space and dedicated time would be essential, argued the committee, to "increas[e] the extent to which 4S members learn from one another about practices they have developed and enacted" (Amir et al. 2014, 3).

Combining the work of an ad hoc committee, involvement of the membership, and council vote could increase the chances that this addition to the meeting infrastructure would become a sticky attachment. All too often in the past, interesting scholarly initiatives that expand knowledge expression in STS had come and gone with their developers. Positioning the program within the annual meeting warranted space in the meeting website, written program, and conference hotel or meeting site. The program belonged to the society as a whole. When, in 2018, a survey was conducted among the 4S membership that included the question "What aspect of the 4S Annual Conference have you found to be especially memorable/impression-making in recent years?," the Making & Doing program was the most frequently mentioned initiative (Futuring/Connecting 4S Ad Hoc Committee et al. 2018).

The sticky attachment came with a sticky challenge. It was not immediately obvious how to assess proposed demonstrations as contributions to STS scholarship. Any scholarly claims that particular practices of STS making & doing produced travel for STS knowledge beyond the field or contributed to further knowledge production in STS would require scholarly judgment to assess. Yet formal inclusion in the meeting program required only a minimal standard of acceptance for individual projects, differentiating only those that clearly positioned themselves within STS from those that fell outside.

ADDING DISTINCTION

When it took the step of recommending that 4S define STS making & doing as a scholarly initiative, the ad hoc committee also deliberated its charge to formulate practices for "assessing exhibited projects and awarding a prize or prizes for the

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highest-quality, most compelling projects" (Downey 2014, 2). This charge was trickier. The committee considered demurring on the grounds that it risked attaching linear model–type calculations to scholarship that is explicitly nonlinear.

Presenting awards to specific projects would certainly contribute to rendering STS making & doing projects and practices legible as potentially "excellent" scholarship. And presenting awards at the annual awards ceremony would ensure that, when the society is recognizing and celebrating its best scholarship, projects in STS making & doing would be there. To not be there (i.e., not be juxtaposed with quality published research at a highly visible moment) could risk eventual decline and return to invisibility. Or worse, it could infrastructure a knowledge hierarchy that formally externalized STS making & doing from STS scholarship, relocating its contributions away from scholarly practices of knowledge expression, travel, and production and toward entertainment or impact.

At the same time, presenting awards risked prioritizing the competitive repertoire that singles out "winning" projects over highlighting the collective benefits of distributed projects and practices that, for the most part, do not compete with one another. Competitions tend to promote the academic mode of "peddling our wares," as panelist Nick Shapiro (University of California, Los Angeles) put it at the 2019 meeting, which had contributed to rendering STS making & doing functionally invisible in the first place. Could recognition via awards take place without also claiming to decontextualize value by introducing a distinction between success and failure? As the demo accounts in this book show, learning through practices of STS making & doing happens through many pathways. These discussions drew partly on international differences in academic infrastructures, with awards joining long, detailed CVs that serve US academic careers in ways they do not in, say, Sweden or the Netherlands. Still, the risk of emphasizing a status economy built on zero-sum calculations, rather than opening up the aperture of what gets to count as STS scholarship, was substantial nonetheless.

With some hesitation, the committee decided to accept the risks of selectively ascribing distinction and recommend the creation of awards. It acknowledged that few other infrastructural practices were available to make this type of work count as scholarship. And it affirmed that an award by an academic society could prove helpful for at least some scholars, who could then produce further work on behalf of a recognized scholarly identity. The committee's final report asserted that new awards would "formally acknowledge and celebrate distinctive achievements" in STS making & doing by "recogniz[ing] 4S members who have demonstrated scholarly excellence in formulating, enacting, and sharing theoretically-informed practices of participation, engagement, and intervention in their fields of study" (Amir et al. 2014, 1).

As discussed below, the ad hoc committee recommended four criteria for assessing projects in STS making & doing, later increased to five by the standing Making & Doing Committee (Society for Social Studies of Science 2015). The many pathways

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through which learning happens through practices of STS making & doing dictated that indicators of quality not be constrained to the narrow channel of impacts or decontextualized distribution through diffusion and utilization. In particular, the awards must be able to honor work that acknowledges and attends to puzzles, struggles, limits, and reflexive learnings that come up through specific practices and configurations of practices.

The 4S Council delegated to the Making & Doing Committee the responsibility to frame practices of assessment that would yield collective peer judgments. The process they built has four steps. The first invites presenters to post abstracts of their projects on the 4S website, along with a photo and web links, as appropriate. Presenters are asked to position their abstracts by drawing on the five criteria. Second, prior to the meeting, committee members examine the web presentations and follow links to other pages in search of promising candidates. Third, during the meeting itself, members visit tables and discuss project practices with individual presenters. And finally, the committee convenes a meeting to discuss, assess, and rank the projects according to the five criteria.

Two of the criteria call direct attention to knowledge expression, to ensure that award-winning projects are producing compelling expressions of STS knowledge. The first criterion, issue of concern, has the effect of stipulating that a given project cannot qualify for an award if it turns out to have not been expressing STS knowledge in the first place. The second criterion adds a quality judgment by looking for evidence of analysis and creativity in how the project expresses STS knowledge.

1. Issue of concern: Does the project foreground a well-defined issue or concept related to the production of knowledge, technology, politics, or other STS-related practices?
2. Critical thinking and creativity: Does the project offer an analysis that contributes to the understanding or problematization of knowledge and expertise in creative ways?

The third criterion explicitly juxtaposes the scholarship of making & doing with research scholarship by asking if the project generates "novel questions or avenues for practice." This criterion speaks directly to those projects that focus on knowledge production, with a key goal of developing new concepts and questions that open up new action repertoires. Without evidence of such new questions and learning, projects in STS making & doing risk signaling that their scholarly contents are limited to outreach. That is, they simplify, dumb down, or vulgarize sophisticated concepts into everyday language, preserving god tricks for knowledge creators and the linear model for knowledge diffusion. By highlighting such learning, projects in STS making & doing gain the potential for contributing to knowledge production in STS even if their primary interest lies in interrogating relations between knowledge expression and knowledge travel through empirical arenas.

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3. Conceptual development: Has the project mobilized its own experimental format as a means to generate novel questions or avenues for practice?

The fourth criterion consists of two parts that both depend on following the travel of STS knowledge into empirical arenas beyond the boundaries of the field. The first part asks if the project offers evidence of how its outcomes extend beyond the installation itself. This part speaks directly to the practices of expression and travel that animate many making & doing projects. The criterion offers a big-tent approach to such practices, asking presenters to develop, demonstrate, and defend them as STS attachments in empirical arenas. It aims to expand participation in STS making & doing even as it seeks to distinguish on the basis of scholarly quality.

The second part of the criterion introduces an expectation that STS scholars who build and demonstrate making & doing projects are learning from their participation in them about how to move beyond what they had imagined possible at the outset. It asks if the outcomes of the project open up new arenas for action or inquiry, so that consequences and responses are experienced both by the arena in which the making & doing initiative is situated and by the STS scholars involved.

4. Consequences and responses: Do the project's implications extend beyond the installation itself? Do the presenters show how their project's outcomes open up new arenas for action or inquiry?

The fifth criterion calls attention to how well the work is presented. STS making & doing projects produce experimental practices of knowledge expression to contribute to knowledge travel and further knowledge production. A quality demo enables audiences to experience the content and force of the learnings they produce and potentially facilitate.

5. Presentation: Is the presentation lively and engaging?

These criteria explicitly prioritize attention to flows of learning that one can see and analyze by following specific practices. Yet what is included in such learning? In a scholarly arena that privileges research, one valued outcome might point directly back to the third criterion, furthering the development of STS concepts. But what about learning that leads to new initiatives interrogating relations between knowledge expression and travel or, perhaps, iterating the first initiative with new or edited expressions of STS knowledge? These moves are quite common in the scholarship of STS making & doing, and the fourth criterion tries to capture them without slipping into diffusionist logics that might homogenize diverse, even contrasting, attachments under the misleading image of impact. The learning and flows might be routed back into further practices of knowledge travel rather than straight to knowledge production. In addition, by iterating and multiplying expressions of STS knowledge and following them into empirical fields, the learning expands practices of expression and travel into a potentially huge research opportunity for knowledge production in STS and for STS as a field: the scholarship of knowledge travel.

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Presenting awards to recognize distinguished projects has, with the limited experience thus far, managed to elevate these novel criteria for assessing STS scholarship, calling attention to themselves as sites for further development and expansion. They infrastructure STS making & doing in a constrained, limited way, via the careers of winners. Yet as one winner told us, "I got that job because of the award." And another said, "This is definitely going into my promotion and tenure dossier."[9]

The program and award committees developed an additional practice to acknowledge and affirm that projects in STS making & doing often do not directly parallel or compete with one another: they destabilized the category of winning. Initially, the committee conferred—as planned—three nonranked awards for equally exceptional projects. One year, however, the committee found it appropriate to confer one "outstanding contribution" award and five "distinguished contribution" awards. And twice, the committee added two "honorable mentions" to the three awards.[10]

As stressed by panelist Max Liboiron (Memorial University of Newfoundland and Labrador) at the 2019 meeting, awards, in the plural, are "super important." At the same time, a small number of awards distinguishes only the few from the many. To be judged as scholarship, practices of STS making & doing also have to offer, and be seen as offering, learning to one another.

ADDING CONNECTION

At the 2018 meeting in Sydney, the Making & Doing Committee pilot tested a discussion format through which commentators give extensive feedback to selected demos. Sara Wylie (Northeastern University) had brought to the committee's attention the *crit*, an established collection of practices in architecture and design schools as well as some maker fairs. In a crit, several jurors offer interpretations of the design elements in a given project, exploring what they "indicate" in relation to audiences, expectations, specifications, future iterations, and so on.[11] Taken with the idea of opening up projects to dive deeper into their practices while also wanting to highlight connections among them, the committee adapted the format to produce the connective crit.

The purpose of a connective crit is to "tease out what [commentators] find particularly interesting when thinking through a cluster of projects within the [Making & Doing] program" (Zuiderent-Jerak and Spencer 2018).[12] Akin to the discussants in a paper session, the format emphasizes "the potential of thinking about [STS making & doing] scholarship as collective and relational." For the meeting, organizing committee members identified four clusters of four to five projects under the themes of "Bringing together and keeping apart knowledges," "Compost, care, time," "Challenging values in design," and "Film as intervention." The committee positioned these projects close together in the physical space of the session and recruited teams of "eminent and up-and-coming discussants" to offer interpretations on the spot.[13]

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The connective crits thereby juxtaposed the making & doing session with the many paper sessions at the meetings that included discussants, as well as with the author-meets-critics sessions honoring prize-winning books. At the same time, the high variability of physical spaces assigned to making & doing sessions at annual meetings makes it difficult to predict how well the format can pull audiences together as the program moves from year to year.

Infrastructuring through meeting programs, awards, careers, and connective criticism is not sufficient to guarantee that other STS scholars will be able to access the practices of knowledge expression in individual projects and assess the extent to which they contribute to the travels of STS knowledge and production of new knowledge. It might be possible at some point to infrastructure STS making & doing in an entirely different way, by stretching the definition of STS methods to include the wide range of specific practices that making & doing scholarship encompasses. The main challenge in this pathway lies in the settled connection that makes methods about research only: they are research methods. The practices involved in expressing STS knowledge through STS sensibilities and attaching those sensibilities to empirical fields includes but exceeds research practices focused wholly on producing new knowledge about those fields. Practices of STS making & doing also produce knowledge about the positioning and possibilities of STS sensibilities within and beyond those fields. They turn lessons from STS research onto STS work, entwining knowledge production with knowledge expression and knowledge travel.

It remains difficult to imagine STS making & doing surviving as a mode of scholarship without extending the technique of juxtaposition to publication, the primary infrastructural marker of scholarly contribution and accomplishment.

PUBLISHING THE VISIBLE SCHOLAR

The contributors to this book all found it important to write in the first person. We were not surprised because we had encountered the issue earlier.

A month before the 2014 joint meeting in Buenos Aires, a team of PhD students chose to present their project on "railographic space" as a fictitious museum. They were one of six teams contributing to an experimental STS making & doing session at their weeklong summer school (Downey et al. 2014). Their project produced a material history of a nearby train platform, built around provoking the "man" in the ticket machine that had replaced the ticket booths about a decade earlier. However, they had run into a problem—they were afraid to press the button marked "SOS" (see figure C.1, with Susan van Hees of Maastricht University hesitating to press the button). How could they adequately produce STS insights and findings about the space and make that knowledge travel to imagined museum goers without pressing that button? If they did not, what would their project be omitting, and why?

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C.1 I can't press SOS!

The moment had produced a discussion on the team of how "our own ethical values" shaped the museum exhibit. Other teams echoed this experience, reporting how their own experimental "perturbations" had tended to produce discomforts in them as both scholars and people. Accustomed to the comfortable distance afforded by performing research methods, they struggled to articulate how they were relating to themselves as persons while undertaking STS scholarship that engaged, participated, and intervened. They recognized that their reactions had become evidence, and anonymity was not an option. Producing and expressing knowledge in ways to

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make it travel into empirical arenas forced an inspection of the self that was both interesting and challenging.

The Making & Doing Committee for the 2017 program encountered the visible self of the scholar in an uncomfortable way. It found itself having to distinguish projects that promised to be critically reflective demonstrations from those that appeared to cross some line between the scholar and the person and become self-promoting performances.[14] Scholarly audiences frequently ignore or discount self-promotion in research presentations by focusing attention on the merits of the research apart from the person of the scholar. A self-promoting demonstration of STS making & doing, however, carries a double threat. It risks undermining evidence and claims about the learning afforded by the project's practices by voiding the scholar as a source of that evidence. Also, self-promotion risks undermining STS making & doing as a mode of scholarship by authorizing claims that it may be impossible to distinguish the scholar in the person from the person in the scholar.

As the team of PhD students discovered, accepting the challenge to make oneself visible in the making & doing project generates a negative criterion: the person beyond the scholar must be left out even as the scholar as person becomes key to the content of the scholarship. Pressing the SOS button and producing an emergency in order to watch the response felt like an intrusion by the scholar on the person, violating the person's obligations as a citizen. And as the Making & Doing Committee found out, evaluators must rely on their own experiences and judgment as scholars to assess the risk of a project descending below the threshold of scholarship into autobiography. In short, juxtaposing STS making & doing with other scholarship extends the boundary work in quality assessment to the personhood of the scholar in the project.

One implication of making the scholar visible in the scholarship is that practices for assessing presentations of STS making & doing scholarship, including in publications, must be anonymous in only one direction. Publishing practices of STS making & doing raise the stakes considerably. As the demo accounts in this book demonstrate, those very moments in which an account reveals or performs commitment or aspiration, making it feel transgressive or otherwise unsafe, may also be providing insights into a key dimension of its scholarly import as practices of knowledge expression and travel. Any criteria for publishing practices of STS making & doing must take into account the visibility of the scholar in the scholarship.

EXTENDING THIS BOOK TO FRAME CRITERIA: AN EXPERIMENT

This book is a demo. It enacts a juxtaposition with published STS scholarship by presenting demo accounts of ten projects. The questions that framed the curation of this volume theorize STS making & doing as expressing STS knowledge through STS sensibilities—observable instances of knowledge expression that enact STS knowledge

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contents but without necessary reference to their formal linguistic formulations. Extending this curation further, the questions that emerged perform a version of possible criteria for informing the further publication of projects and practices of STS making & doing. Picture the aims and scope for a journal, a section of a journal, or a book series defining STS making & doing and then drawing on this book to specify criteria for assessing manuscripts.

Might they look something like this?

---

1. This project identifies and addresses important frictions in science, technology, or medicine.

Associated questions: How does this project construe the frictions it identifies? Is the friction about subordination, demarcation, presupposition, invisibility, multiplicity, obligation, some combination of the above, or what? Might the friction be stable or shifting? How does the way this project identifies a friction open up or close down potentials to engage with its actors and practices? Does this project aim to smooth, interrupt, displace, replace, introduce, reframe, keep open, or maximize a friction, or perhaps just get a localized setting to recognize a friction in the first place? Something else?

2. This project expresses STS sensibilities for other audiences and settings.

Associated questions: What STS sensibilities does this project produce and express? What evidence does the project give to document these sensibilities as expressions of STS knowledge? Do these sensibilities include techniques, devices, infrastructures, or selves? Other specific practices? Does the production of STS sensibilities in this project anticipate specific audiences and specific attachments in empirical settings? What evidence does the project give of anticipated learning through STS sensibilities?

3. This project produces knowledge travel by attaching STS sensibilities in one or more empirical arenas.

Associated questions: How does this project attach STS sensibilities in one or more settings? Through what specific practices? What do STS attachments add? Subtract? What are their actual material lives and trajectories, with what spatialities and temporalities? What evidence does this project present of STS learning in the empirical arena? What challenges to the travel of STS sensibilities does this project face and attempt to overcome? How does this project frame entry points for a given STS sensibility? How does this project encounter and interact with other sensibilities that may be active in the setting or also be seeking attachment? Do other attachment arenas appear open to the STS sensibilities in this project?

4. This project produces reflexive learning by the STS scholar (e.g., iterating STS sensibilities, generating new STS knowledge).

Associated questions: How does STS learning in the empirical field speak to the initial framing of a friction? Does the attachment of STS sensibilities open up other sensibilities and attachments via other techniques, devices, infrastructures, and bodies? How or how not? What evidence does the project present of learning within it? Does the achievement of learning in empirical settings motivate new STS research? What might be next for this project? Another phase of the current

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project, to further extend the reach of its sensibilities and learning? Another project? New theorizing of knowledge production, expression, and travel?

5. This project addresses issues raised by the visibility of the STS scholar.

Associated questions: How does this project make and do the scholar in the scholarship? With what evidence? Does the attachment or non-attachment of STS sensibilities in the empirical arena mark experiences with affective contents? With what evidence? Does the project address relations among the scholarly and nonscholarly identities of the STS scholar as person? Does the project as presented avoid becoming ad hominem or ad feminam, escaping autobiography and self-promotion? Does the project produce boundary-crossing claims, enabling the scholar to remain relatively invisible as a person? Does the project produce meta-activism, making the scholar visible in a restricted sense, as ally of activists who serve as audience? Does the project experiment with participation, challenging the scholar to accept opportunities, risks, and uncertainties that come with seeking travel for STS learning?

6. This project advances STS theorizing of STS making & doing.

Associated questions: How does this project critically frame or reframe the expression of STS knowledge and its travel into empirical fields? How does it theorize the production and flow of STS techniques, devices, infrastructures, selves, and so on, that go beyond the linguistic representation of research findings? How does the project further STS knowledge about the trajectories of STS knowledge beyond the boundaries of the field? How does this project theorize the opportunities and constraints for STS scholars and scholarship that come with making the scholar visible in the scholarship? How does this project advance theorizing about science, technology, and society?

Examples in this volume.

Go back to the chapters!

EXTENDING THE NARRATIVE?

Demo accounting for the expression and travel of STS sensibilities, and the reflexive flows of learning they produce, points STS scholars toward storytelling narratives. Learning happens through the plotlines of projects and the practices they enact. The scholarly work of infrastructuring projects and practices of STS making & doing does the same. It challenges the scholars involved to frame narratives to demonstrate and account for where the scholarship is, how it got to be where it is, and where it might go from where it is, whether as one thing or many.

The narrative in this coda leaves open many questions about infrastructuring STS making & doing into careers, departments, grant programs, and other arenas in which STS scholars do their work and seek credit for it. It shows that making and doing the scholarship of making & doing within STS is clearly as challenging as it is to build a project that expresses STS knowledge through STS sensibilities, attaches them in empirical arenas beyond the boundaries of the field, and produces reflexive learning that contributes to the field.

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Turning STS lessons onto STS work is an intellectual commitment and an opportunity for new learning. It is also an alert that the scholarly infrastructures through which STS scholarship gets done both enact and enforce what gets to count as that scholarship. The scholarship of STS making & doing activates STS through nonlinear forms of knowledge expression and travel. Pulling that work into scholarly infrastructures and enabling it to claim credit also helps ensure that STS knowledge does, in fact, attach to empirical arenas beyond the boundaries of the field.

NOTES

1. Confidential conversations, September 6, 2019, New Orleans, Louisiana. Cited with permission.

2. Informal comments, September 6, 2019, New Orleans, Louisiana. Cited with permission.

3. See https://www.4sonline.org/sts-resources/making-and-doing/ where all previous contributions, including a number of those included in this book, are present and can be searched through all years a Making & Doing program was curated.

4. Society for Social Studies of Science (4S) (2014). The full name of ESOCITE is Asociación Latinoamericana de Estudios Sociales de la Ciencia y la Tecnología.

5. Pablo Kreimer, president, Asociación Latinoamericana de Estudios Sociales de la Ciencia y la Tecnología (ESOCITE), and Gary Downey, president, Society for Social Studies of Science (4S).

6. Juxtaposition through the presidential plenary was repeated at the 4S meeting the following year under the title "Making & Doing II: The Formation and Ecologies of STS Practitioners." Also, the organizing committee plenary at the 2017 annual meeting, titled "Opportunities and Challenges for an Engaged STS," added further infrastructural support. Panelists there drew on projects to discuss the "possibilities and responsibilities of public engagement, political activism and advocacy, policy-making, pedagogy, transdisciplinary collaboration, and other forms of STS scholarship and engagement" (Society for Social Studies of Science 2017).

7. 4S Council members included Sulfikar Amir (Nanyang Technological University), Gary Downey (president, Virginia Tech), Kenji Ito (Sokendai, Graduate University for Advanced Studies), Sunder Rajan Kaushik (University of Chicago), Abby Kinchy (Rensselaer), Wen-Hua Kuo (National Yang-Ming University), Vivian Lagesen (Norwegian University of Science and Technology), Kelly Moore (Loyola University Chicago), Leandro Rodriguez-Medina (Universidad de las Américas Puebla), and Claire Waterton (Lancaster University). Contributing 4S officers included Paige Miller (treasurer, University of Wisconsin–River Falls), Wes Shrum (program officer, Louisiana State University), and Steven Zehr (secretary, University of Southern Indiana).

8. Amir et al. (2014). The committee chose a science fair approach, in which a large number of presentations are invited to participate, over an art exhibition approach, in which a small number of proposals are selected for the exhibit. The 4S Council had previously made an initial move beyond the academic paper by adding to annual meetings the screening of ethnographic films.

9. Confidential conversations.

10. The committees have included the following members. Denver, 2015: Sulfikar Amir (chair, Nanyang Technical University), Joe Dumit (University of California, Davis), Chia-Ling Wu (National Taiwan University), Sara Wylie (Northeastern University), and Teun Zuiderent-Jerak (Linköping University). Boston, 2017: Anita Say Chan (University of Illinois), Gary Downey (Virginia Tech), Catherine Dignazio (Emerson College), Max Liboiron (Memorial University of Newfoundland and Labrador), John Lunsford (Cornell University), Sara Wylie (chair, Northeastern University), and Teun Zuiderent-Jerak. Sydney, 2018: Anita Say Chan (University of Illinois),

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Nick Shapiro (University of California, Los Angeles), Michaela Spencer (Charles Darwin University), and Teun Zuiderent-Jerak (chair). New Orleans, 2019: Endre Dányi (Goethe University), Laura Forlano (Illinois Institute of Technology), Gwen Ottinger (Drexel University), Martín Pérez Comisso (Arizona State University), Wen-Ling Tu (National Chengchi University), and Teun Zuiderent-Jerak (chair, Vrije Universiteit Amsterdam).

11. For discussion of how such "indication" can include "pathway" and "directionality" for knowledge travel, see Downey, demo account 10 in this volume.

12. This newsletter is emailed monthly to all members of the 4S.

13. Connective crit discussants were, in order of the topics as listed in the text, Endre Dányi (Goethe University) and Radhika Gorur (Deakin University), Sebastián Ureta (Universidad Alberto Hurtado), Annalisa Pelizza (University of Twente), and Juan Salazar (Western Sydney University).

14. Confidential observation.

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CONTRIBUTORS

All Our Teachers (see demo account 6) refers to the shoulders we stand on as thinkers and authors, all the humans and nonhumans that have taught us whose traces in our writing are significant even if they are not coauthors. Thank you.

Edward Allen (he/him) is Kallunangajuk from Nunatsiavut and a student in the Geography Department at Memorial University. His research interests include Land-based wellness practices.

Lucas Becerra is associate professor of international economics at the National University of Quilmes (UNQ). He works as a researcher at the Institute of Science and Technology Studies (IESCT-UNQ) and he is assistant researcher at the National Scientific and Technical Research Council (CONICET).

Andreas Birkbak is associate professor of techno-anthropology and digital organizing in the Department of Culture and Learning at Aalborg University in Copenhagen. He has published a book in Danish on digital methods with fellow Techno-Anthropology Lab member Anders Kristian Munk, and he has been a visiting scholar at Sciences Po and Ecole des Mines in Paris, and at Goldsmiths and Warwick University in England.

Katherine Carroll is a senior lecturer and qualitative researcher of health services in the School of Sociology at Australian National University.

Hsin-Hsing Chen is a professor at the Graduate Institute for Social Transformation Studies at Shih-Hsin University. He has been active in environmental, labor, and other social movements in Taiwan since the 1980s.

Gary Lee Downey is Alumni Distinguished Professor of Science, Technology, and Society at Virginia Tech. His books and other publications are STS devices to critically inflect dominant images and practices of technology, engineering, engineers, and knowledge.

Torben Elgaard Jensen is professor in science and technology studies, leader of the Techno-Anthropology Research Group, and a member of the Techno-Anthropology Lab at Aalborg University. His research examines innovation, knowledge construction, and user involvement across a range of different contexts.

Michael Guggenheim is a reader at the Department of Sociology at Goldsmiths and codirector of the Centre for Invention and Social Process.

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Paula Juarez is associate professor of sociology of organization and public policy praxis at the National University of Quilmes (UNQ). She works as a researcher at the Institute of Science and Technology Studies (IESCT-UNQ), and she is national coordinator of the Programa SEDCERO.

Bernd Kräftner is an artistic researcher and teaches at the Departments of Art & Science and Digital Arts at the University of Applied Art, Vienna.

Judith Kröll is a sociologist of science and cofounder of the group shared inc. She is associated with the Department of Science and Technology Studies at the University of Vienna.

Max Liboiron (they/she, Michif/Métis, and white) is associate professor of geography at Memorial University of Newfoundland and director of CLEAR, which is an incubator for anticolonial science methodologies.

Yi-Ping Lin is associate professor at the Institute of Science, Technology and Society at National Yang-Ming University in Taiwan. She has a background in public health and has been participating in RCA research and the lawsuit for more than twenty years.

Anders Koed Madsen is associate professor in digital knowledge organization at Aalborg University. He is a founding member of the Techno-Anthropology Lab, where he studies the emergence of digital metrics in the professional vision of architects and contributes to the development of computational humanities.

Charles Mather (he/him) is professor in the Department of Geography at Memorial University of Newfoundland, St. John's. He is a guest on the traditional territories of the Beothuk and Mi'maq people. His research focuses on the biopolitics of salmon (and other fish) in Newfoundland, Canada, and beyond.

Jessica Melvin (she/her) is a settler from Newfoundland and Labrador. She is a researcher and project coordinator at Memorial University of Newfoundland, where she currently leads the Placentia Bay Ocean Debris Survey (PODS).

Jessica Mesman is associate professor in science & technology studies at Maastricht University in the Netherlands. Her field of expertise is the analysis of medical practices by using an "exnovative" approach and the method of video-reflexive ethnography.

Anders Kristian Munk is associate professor in techno-anthropology and director of the Techno-Anthropology Lab at Aalborg University. His research focuses on technoscientific controversies and the role of online media in democratic debate. Anders has a particular interest in methods development for digital STS and computational anthropology.

Dawn Nafus is a senior research scientist at Intel, where she conducts anthropological research to develop new products and strategies. Her research focuses on health and environmental sensing, data and measurement, and digital research methods.

Nicholas Shapiro (he/him) is an assistant professor of biology and society at the University of California, Los Angeles.

Emily Simmonds is a Métis-settler scholar working at the intersection of anthropology and feminist science and technology studies. Her research interests include environmental health and racism, the materiality of colonialism, and the politics of evidence.

Hernán Thomas is professor of sociology of technology at the National University of Quilmes (UNQ). He is director of the Institute of Science and Technology Studies (IESCT-UNQ), a research center associated with the Buenos Aires Scientific Research Council (CIC-BA), and principal researcher at the National Scientific and Technical Research Council (CONICET).

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Emily Wells (she/her) is a settler from Newfoundland and Labrador. She is a researcher with broad interests that center around equity and opposing colonialism.

Alex Zahara (he/him, settler) is an interdisciplinary scholar and PhD candidate in the Department of Geography at Memorial University of Newfoundland. His research focuses on settler colonialism and wildfire management practices near his home community of Prince Albert, Saskatchewan, on Treaty 6 Territory, the homelands of Cree, Dene, Dakota, and Métis people.

Teun Zuiderent-Jerak is associate professor of transdisciplinary science & technology studies at the Athena Institute, Vrije Universiteit Amsterdam. His work explores how the direct involvement of STS scholars in the practices they study can lead to the production of new knowledge and new normativities.

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